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The effects of selected pre-germination treatments on six species of summer and winter annual plants of the east Mojave Desert

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THE EFFECTS OF SELECTED PRE-GERMINATION TREATMENTS ON SIX SPECIES OF SUMMER AND WINTER ANNUAL PLANTS OF THE EAST MOJAVE DESERT.

A Thesis

Presented to the

Faculty of California State

College, San Bernardino

by

James R. Earsom

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ABSTRACT

Seeds from six annual species of desert plants, *Allonia incarnata* L., *Amaranthus fimbriatus* (Torr.) Benth., *Bouteloua barbata* Lag., *Eriogonum deflexum* Torr. ssp. *deflexum, Eriogonum nidularium* Cov., *Pectis papposa* Harv. and Gray ex Gray, were collected and subjected to various pre-treatments to determine what effect these pre-treatments would have on the germination response of the six species collected, specifically summer and winter annual germination patterns.

Pre-treatments consisted of heat (50°C for one week), scarification of seed coat, soaking and rinsing, compaction of soil medium, use of rainwater vs. distilled.

Results showed that *A. fimbriatus, B. barbata* and *P. papposa* fall under the classification of summer annual. *E. deflexum* ssp. *deflexum* and *E. nidularium* fall into the category of winter annual. The results for *A. incarnata* were inconclusive. Compaction of the soil medium and use of rainwater had no significant effect on the germination response for any of the six species studied.

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INTRODUCTION

Relatively little is known about the basic seed germination requirements of summer and winter annual plants of the Mojave Desert. A brief unpublished list of these plants has been compiled by the Desert Planning Staff of the Bureau of Land Management (BLM) and is available from the Riverside District offict of the BLM (Riverside, California). Although some seed germination studies have been conducted (Went, 1948, 1949, 1956; Newman 1963; Janssen 1974; Tevis 1958; Pemedasa and Lovel 1975; Capon and Van Asdall 1967; Davidson and Fox 1974), more information is needed to provide a better understanding of the germination requirements for summer and winter annual plants. Information concerning germination requirements in the broad array of desert annuals is expected to provide useful information to land managers involved with writing environmental impact atatements relating to the effects of powerline installation, road building, mining, grazing and recreation. Basic knowledge of seed germination and seedling physiological requirements may allow a better planning base to satisfy the possible need for re-establishment of any type of ground cover in desert areas in which potential damage is expected from the various uses. Also rehabilitation of plant cover in areas already damaged depends on basic requirements for ecesis of plants. The importance of ground cover in minimizing the effect of wind and water erosion is significant (Wilshire and Nakata 1976).

The primary factor for seed germination is water availability

(Noy-Meir 1973; Beatley 1967 and 1974; Tevis 1958; Went *et al* 1956, 1949). Thus, rainfall patterns in the Mojave Desert (Bailey 1966; Felton 1965) will be discussed.

Another major factor influencing germination is temperature. Air temperature ranges for the Mojave Desert will be reported (Buckman and Brady 1967).

Although general methods for testing seed germination requirements have been developed for and directed toward vegetable crops seeds, these methods are applicable to other kinds of plants as well. According to Justice (1961), more research has been done on the garden bean than on any other single crop plant. Such general techniques as in those studies used are of value in all other determinations of seed germination requirements. Seed dormancy and the factors that break this dormancy, particularly in cereal and grass seeds, has been a major area of research (Justice 1961). Prior to 1961, seed testing was based primarily upon observed emergence of the radicle. Germiantion was considered to have occurred with that event. Since then, the considered definition of seed germination has come to include various components of later survival of the seedling as well depending on the viewpoint of the investigator. Thus, some workers include successful establishment of the seedling as a criterion in determining germination success (Justice 1961). Additionally, earlier seed germination studies often failed to provide correlation of results gained in the laboratory setting with conditions in the field. In these areas, as pointed out by Justice (1961) the value of the results is questionable.

Kinds and treatment of substrates normally used in seed germination studies are primary considerations in experimental design. The substrates used routinely are blotters, paper-towels, sand and soil, filter paper, cotton, creped cellulose, paper wadding, peat moss, sawdust, or mica. Not all of these substrates have standards dealing with thickness, consistency, chemical contents, moisture absorption, water holding capacity. Some of the substrates have other faults (e.g., sawdust contains toxic materials injurious to the germination of seeds.) Selection of a proper substrate with uniform characteristics is desirable to better provide standard conditions for germination.

Basic standards for setting experimental conditions for such factors as moisture, temperature and light levels in seed germination studies have been formally established (USDA 1952), through the cooperatuve efforts of various agricultural organizations. These guidelines provide a common base for design of all seed germination experiments. Criteria for dealing with fungal contamination and seed dormancy problems have also been established (USDA 1952).

Additionally, the effect of soil compaction on seed germination is considered potentially significant (Davidson and Fox 1974; Wilshire and Nakata 1976). The consideration of the effect of soil compaction on seed germination is integral to any study dealing with seed germination parameters in the Mojave Desert due to heavy off-road vehicle traffic in this desert.

In most studies, agronomic crops were used to study the effect of soil compaction on seed germination. Phillips and Kirkham (1962) measured bulk density of the soil by the mechanical impedence to needle penetration. Their results showed that an increase in soil compaction markedly reduces growth and yield of corn.

Klop *et al* (1967), working with winter wheat, found a direct relationship between coleoptile length and intensity of soil compaction; the greater the soild compaction, the shorter the coleoptile length.

Kabota and Williams (1967) found a direct correlation between increased percentage of germination of barley or globe seeds and the absence of compaction. However, seeding survival increased slightly with light compaction.

Davidson and Fox (1974) studied the effects of off-road motorcycle activity on the Mojave Desert vegetation and the soil, and concluded that areas having heavy damage by compaction were no longer suitable as a seed germination bed.

Tevis (1958) working with ephemerals in the Coachella Valley discovered that natural rain caused greater levels of seed germination than had occurred in artificial watering. This was consistent for all species that he studied. Also, Johnson *et al* (personal communication 1978) found significant differences in germination after rains versus sprinkling with water.

Generally, the separation in time of seed-set between summer and winter annuals prevents collection of seeds from both groups at the same time in the same set of general environmental conditions. Yet, on August 5, 1977, this problem was overcome in the present study due to heavy rains from tropical storm Doreen which stimulated germination and growth of both summer and winter annual plants and provided a unique opportunity to collect seeds from both types simultaneously in the Mojave Desert.

The purpose of this study is to determine whether germination responses may provide a distinct classification of these plants with summer or winter annual status. Various factors of potential significance were considered, separately and in combination, which tend to modify the germination response in the seeds of six selected species of desert annual plants.

STUDY AREA

The general area from which seeds were collected is located in the East Mojave Desert Region approximately 58 kilometers southeast of Baker, California. The locations of five specific seed collection sites are shown in Figure 2.

a.) Description of Site I

The elevation of Site I is approximately 1256 m. The soil according to Hansen *et al* (1976), is a gravelly loamy sand. The surface is nearly level with little slope. *Amaranthus, Bouteloua* and some *Pectis* seeds were collected here. This site, shown below, in Fig. 1, was being grazed at the time of seed and soil collection..

Figure 1: North facing view from Wildhorse Canyon Road (Site I): 1.0 mile west of junction with Black Canyon Road. (T11N R15E NE1/4 of the SW1/4 section 18).

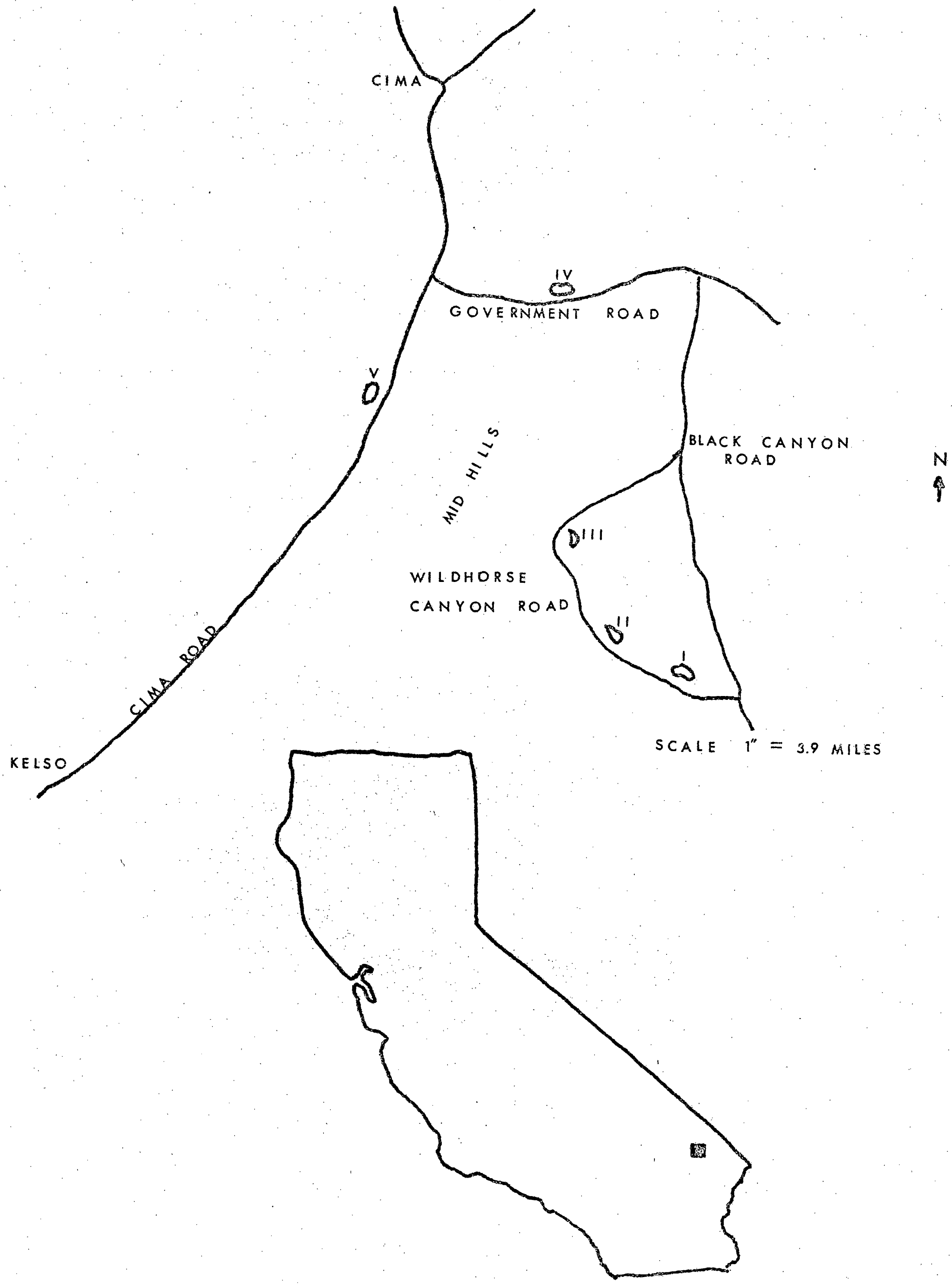


Figure 2: Location of Study Area and Study Sites in the East Mojave

b.) Description of Site II.

Site II (Fig. 3) is approximately 1365 m in elevation and nearly level. *Bouteloua*, *Amaranthus* and *Pectis*, and the two species of *Eriogonum* were collected here. The soil is generally the same as at Site I, with grazing also in effect here.

Figure 3: Northeast facing view from Wildhorse Canyon Road (Site II): 2.7 miles west of junction with Black Canyon Road (T11N R14E SW1/4 of the NE1/4 section 12).

c.) Description of Site III

At site III, a northeast facing roadbank, only the two species of *Eriogonum* were found. There was no grazing evident and the elevation is 1451 m. The soil here is very coarse textured and very shallow (15-51 cm) according to Hansen *et al* (1976). A general view of the terrain is shown in Figure 4.

Figure 4: West facing view toward Wildhorse Canyon Road (Site III): 4.2 miles west of the junction with Black Canyon Road (T11N R14E SE1/4 of the NE1/4 section 2).

d.) Description of Site IV.

Site IV is 1268 m in elevation with little slope. The two species of *Eriogonum* were found here along with *Pectis*, *Bouteloua* and some *Amaranthus*. The soil is of the same type as that found at Sites I and II. There had been some grazing here, but not in the previous few months. In this case, the plants from which seeds were collected were growing in a disturbed area, the road-side ditch. Figure 5 shows the characteristics of this site.

Figure 5: East facing view of north ditch alongside Government Road (Site IV): 4.3 miles west of junction with Black Canyon Road (T13N R14E SE1/4 of the NW1/4).

e.) Description of Site V

Site Five is 927 m in elevation. Although lowest in elevation of the five sample sites, the slope and soils are the same as Sites, I, II and IV. *Allonia, Pectis, Bouteloua* and some *Amaranthus* seeds were collected here. No signs of grazing were present. The site is located near the transition between Joshua Tree Woodland and Creosote Bush Scrub in that area.

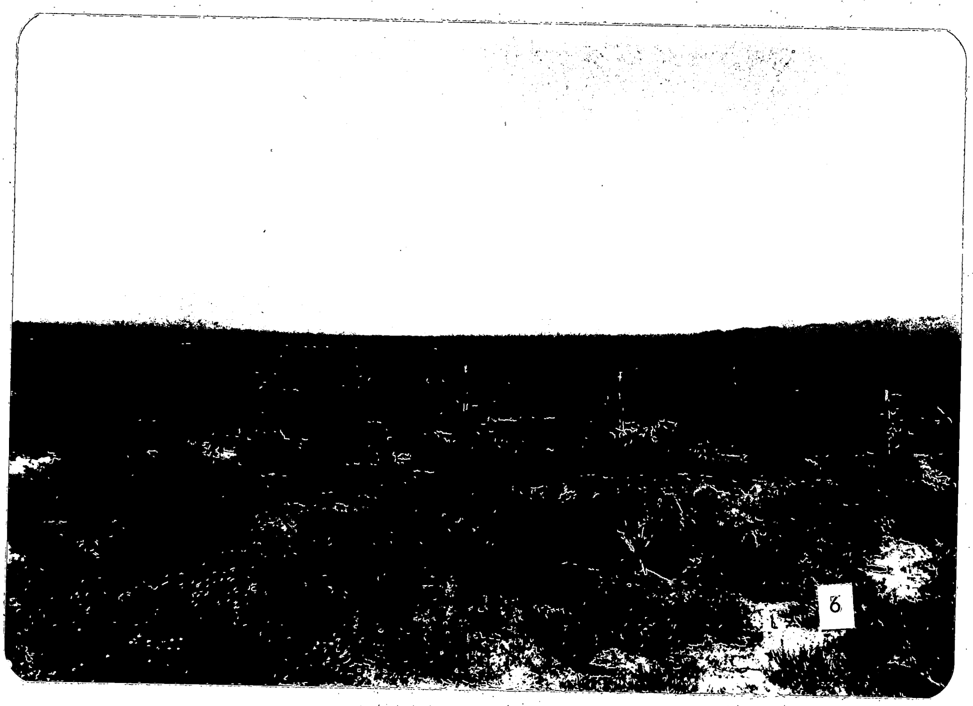


Figure 6: West facing view from Cima Road (Site V): 10.5 miles northeast of Kelso, California (T12N R14E NW1/4 of the SW1/4 section 7).

Air temperature ranges for the Mojave Desert are shown in Table 1. Surface soil temperatures generally show a greater annual range than the air and are often 10°F warmer than air temperatures. Changes in soil temperature, except at the very surface, are gradual while the air may vary many degrees in a very short time (Buckman and Brady 1967). Rainfall patterns in the Mojave Desert (Bailey 1966; Felton 1965) are summarized in Table 1 as well.

Table 1: Summary of precipitation and temperature ranges at selected sites in the Mojave Desert (Bailey 1966; Felton 1965).

	Mean Annual Ppt.	Mean Summer Ppt.	Mean Temperatures July	January
Barstow	10.8 cm.	1.8 cm.	28.9°C	7.6°C
Twenty-nine Palms	10.7 cm.	4.1 cm.	31.3°C	8.9°C
Needles	11.8 cm.	3.8 cm.	34.6°C	10.7°C

A summary of sites from which the six species were collected is shown in Table 2.

Table 2: Species collected from the five study sites. (A = *Allionia incarnata*; B = *Amaranthus fimbriatus*; C = *Bouteloua barbata*; D = *Eriogonum deflexum*; E = *Eriogonum nidularium*; F = *Pectis papposa*.

Study Areas	Species A	B	C	D	E	F
I	-	+	+	-	-	+
II	-	+	+	+	+	+
III	-	-	-	+	+	-
IV	-	+	+	+	+	+
V	+	+	+	-	-	+

MATERIALS AND METHODS

Following field observations conducted during May-August 1977, six annual plant species were selected for study. The main criteria for selection of species were access, abundance and time. More abundant forms were selected for study to insure a larger seed supply, and because of access difficulties selection of collection sites was limited to those located near maintained roads. Seeds are pictures in Figure 7.

I. Seed Characteristics of Plant Species Studied

a.) *Allionia incarnata* L.: The seeds are straw-colored, about 2 x 3 mm in size, with incurved margins. The plant is a low growing winter annual, sometimes classified as a perennial (Munz 1974). At the collection sites, trailing branches of the plants criss-crossed forming a mat of vegetation on the desert floor. Seeds of nearby plants, such as *Pectis papposa* Harv. and Gray ex Gray and *Bouteloua barbata* Lag., as well as those of *Allionia* were often found between the teeth on the inner surface of *Allionia incarnata* L. seeds, attached by two rows of sticky glands which are found there.

b.) *Amaranthus fimbriatus* (Torr.) Benth: The somewhat flattened, disc-shaped seeds of this plant are about 0.8 mm in diameter and shiny black. Each individual plant produces large quantities of seed, thus relatively few plants, compared to the other species collected, were harvested. According to Went (1948), this species is a summer annual.

c.) *Bouteloua barbata* Lag.: The straw colored seeds are approximately 0.3 x 0.8 mm in dimensions, the smallest seeds

Figure 7. Flowers, fruits and seeds of materials used: a) *Allionia incarnata* fruit and seed, b) *Amaranthus fimbriatus* flowers and seed, c) *Bouteloua barbata* flowers and fruit, d) *Eriogonum deflexum* flowers, fruit and seed, e) *Eriogonum nidularium* flowers, fruit and seed, f) *Pectis papposa* seeds attached to leaf of *Allionia*.


a
d
b
e
c
f
1 Cm

of the six species. Large dense populations of this species occur at roadsides, but can easily be overlooked because of the prostrate culms and light color of the individual plants. During the time of seed gathering small sample areas of less than one square meter yielded thousands of seeds (Went 1948) classifies this species as a summer annual.

d.) *Eriogonum deflexum* Torr. ssp. *deflexum*: The dark colored seeds, approximately 1.5 mm long, have an elongated beak giving them a flask-like appearance. The seeds from this winter annual (Went 1948) were collected in disturbed areas within each of the respective collection sites.

e.) *Eriogonum nidularium* Cov.: The dark colored seeds of this plant are very similar to those of *Eriogonum deflexum* Torr. ssp. *deflexum*. Although the seeds of both species are quite simlar, the vegetative plant structure of *E. nidularium* is much smaller with branches more compact, than *E. deflexum*. The species is similarly classified by Went (1948) as a winter annual.

f.) *Pectis papposa* Harv. and Gray ex Gray: The seeds, approximately 5.0 mm long and 0.3 mm in diameter, are black in color when mature. This species was found in abundance at only one site. The population was large and extended for miles past the collection area giving the desert floor a yellowish green appearance. This summer annual species (Went 1948) was found growing intermingled with *Allionia*.

III. Treatment of Plant Materials Before Testing for Germination in Selected Temperatures

Seeds were harvested by collecting whole plants for later separation of the seeds in the laboratory, except in cases where mature seeds had already been shed. Collection of seed of *Pectis papposa* differed somewhat in that the *Pectis* seeds were clinging to the sticky glands of *Allionia* seeds and to other plant parts. By gathering whole plants of *Allionia, Pectis* seeds were collected as well.

After the collections were completed and during the time needed for separating the seeds, the plant material was maintained as much as possible at 6°C in a Precision Scientific Safety Refrigerator Model 801 in order to help preserve seed viability until specific treatments and germination tests commenced (eight weeks later).

Because of the number of treatments for each species, a flow diagram (Fig. 8) was used to organize the preparation of each lot of seeds before it was placed in conditions of germination. Pre-treatments are coded in Table 3. The first pre-germination treatment consisted of placing a portion of the seeds of each species in dry incubation for one week at 50°C in contrast to the 6°C storage temperature. Similar heat treatments for various time intervals were found to be effective in increasing germination of annuals by Capon and Van Asdall (1966), with the majority of their species exhibiting maximum germination after pre-treatment for one week of incubation at 50°C. The remaining seeds of all species in the present study were retained at 6°C.

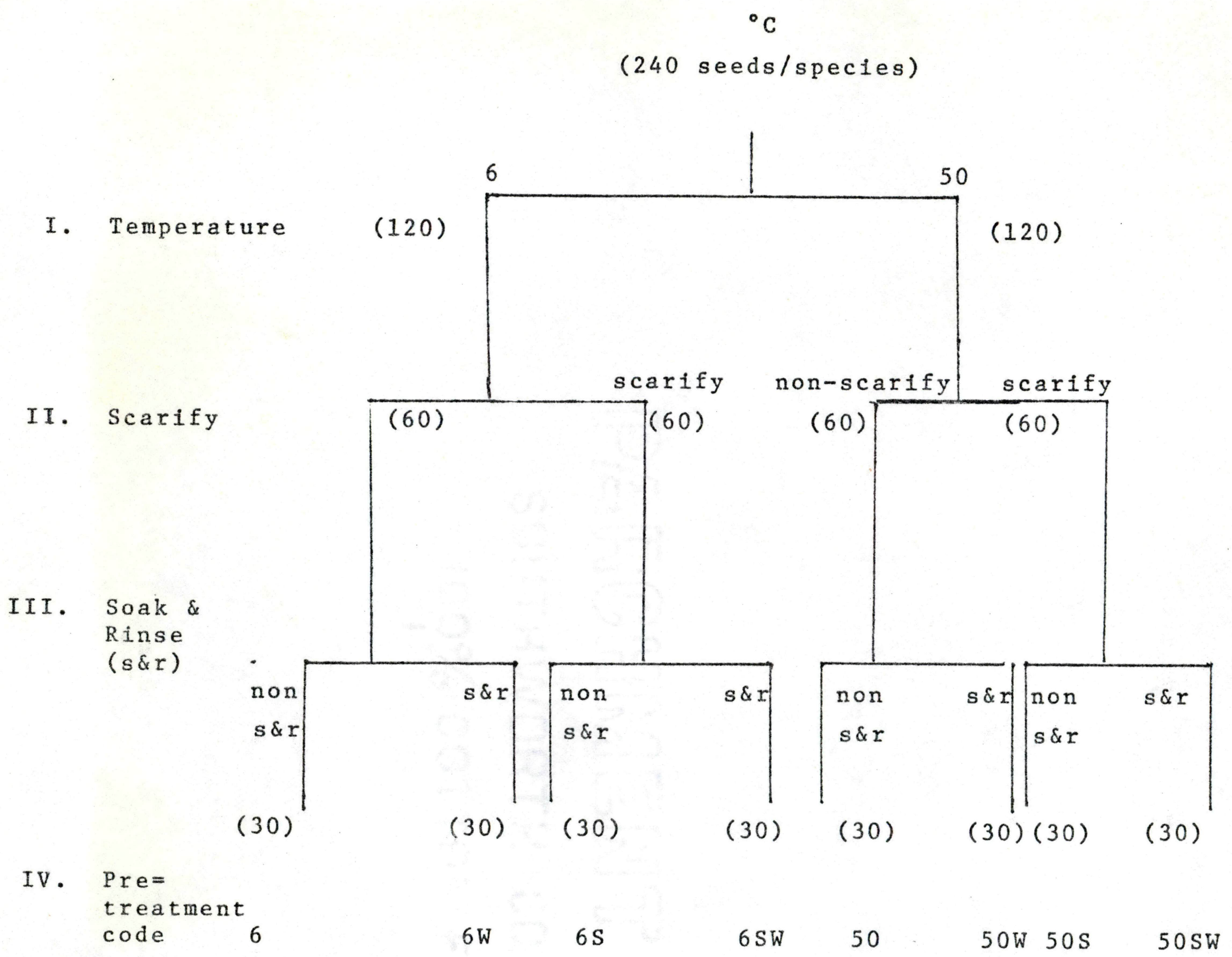


Figure 8: Schema for pre-germination treatment prior to placing seeds in germination conditions.

Table 3: Code symbols for pre-germination treatments as outlined in Fig. 8.

Code		Treatment
6	:	Seeds stored at 6°C until placed in germination conditions.
6W	:	Seeds stored at 6°C, soaked and rinsed in distilled water, then placed in germination conditions.
6S	:	Seeds stored at 6°C, scarified, then placed in germination conditions.
6SW	:	Seeds stored at 6°C, soaked and rinsed in distilled water, scarified, then placed in germination conditions.
50	:	Seeds incubated at 50°C for one week, then placed in germination conditions.
50W	:	Seeds incubated at 50°C for one week, soaked and rinsed in distilled water, then placed in germiantion conditions.
50S	:	Seeds incubated at 50°C for one week, scarified, then placed in germination conditions.
50SW	:	Seeds incubated at 50°C for one week, soaked and rinsed in distilled water, scarified, then placed in germination conditions.

A portion of the heat-treated (50°C) seeds were scarified using an Eberbuck Mechanical Shaker in which coarse sand paper was placed in the bottom. A flat weight of 113.3 g (21 x 28 cm) was placed atop the seeds during shaking to prevent their inadvertant bouncing out of the tray. Scarification continued for five minutes at the fastest setting of the mechanical shaker. Equal numbers of heat-treated seeds of each species were left unscarified.

Similarly, seeds held at 6°C were divided into two equal lots, one scarified and the other lot left unscarified.

At this stage in pre-treatment, four sub-groups of seeds were available; non-heat treated non-scarified; non-heat treated scarified; heat treated non-scarified; heat treated scarified. Each of these groups in turn were divided in half, one half being subjected to soaking and rinsing procedures, and the other half not. Soaking time in distilled water for seed lots subjected to soaking and rinsing was one hour. This was followed by rinsing in fresh distilled water.

The products from this pre-treatment series provided eight lots in the various ways outlined in Figure 8. After pre-germination treatment was completed, 240 seeds for each species (30 seeds per pre-germination treatment) were spread on paper towels and placed in the germinator. Total seeds tested for each species at the temperatures listed below at the seven programmed temperatures was 1,680.

Germination tests were conducted in programmed conditions established in a Conviron Controlled Environment Seed Germinator Model G-30. Temperature, humidity and light are variables which can be programmed in any combination. In all germination tests humidity was kept at a constant setting and was not a variable. Temperatures tested included 10°C, 15°C, 20°C, 25°C, 30°C, 35°C and 40°C.maintained at ± 2°C over respective 14-day germination spans. In the experiment at 10°C, the germination span was reduced to 10 days instead of 14 due to equipment failure. However, the designated temperature of 10°C ± 2°C was was held during the 10-day period.

The light program was eight hours of light, alternating with 16 hours of darkness, following the standard procedures of Capon and Van Asdall (1966) and Went (1949). The length of the 16-hour dark period is sufficient to allow germination of both short or long day plants if seeds are light sensitive.

While atmospheric humidity was held constant in the germinator, it was necessary to add distilled water to the paper towels on which the seeds were placed to retain the necessary moisture at the seed surface for germination. Necessary levels of moisture were determined by finger pressure to ascertain that water would pool on the surface of the paper towel. This was particularly the case at higher germination temperatures. Observations on germination for all seed lots were made daily. Germinated seeds were counted and removed each day.

IV. Effects of Soil Compaction and Rain Water vs. Distilled Water on Germination.

Pre-germination treatment of seeds used in this phase of the study included dry incubation at 50°c for one week, followed by soaking and rinsing, but without scarification. This pre-germination schedule was chosen on the basis of its promoting optimum germination in all species during the first phase of this study.

Soil samples were collected from each of the five study sites. Samples were taken from the uppermost two to three centimeters of soil, which corresponded to the layer of the soil in which seed germination normally occurs. Each soil sample was spread out in a thin layer and all seeds contained within it removed with forceps. The soil amples were then ready for use as a germination medium.

Rain water was collected during the winter season of 1978 from several rain storms occurring at the California State University and Colleges Desert Studies Center at Soda Springs located 18 kilometers south of Baker, California.

For the soil compaction study, plastic pots were used. The surface area of the pots is 167.8 cm^2. Thirty seeds were placed in each of the six pots per species. The pots were first nearly filled with gravel as a support matrix which was then covered with a 15 mm layer of soil collected from the study sites. The seeds were placed atop the first soil layer and then covered with an additional 15 mm layer of soil. Three pots for each species were brought to field capacity with rain water and the other three with distilled water. Field capacity is defined as the amount of water remaining in the soil micropores after free water drains from the macropores by gravity (Buckman and Brady 1967).

After field capacity had been obtained, compaction of the soil was accomplished by use of a Carver Laboratory Press Model "C". A rigid wooden template (3.8 cm thick) was cut to fit exactly the inside diameter of the pots to insure equally applied pressure over the entire surface of the soil. To determine the actual pressures applied to the soil surface, a conversion factor was calculated which translated rated pressures at the hydraulic piston face to expected pressure spread evenly over the larger area of the wood-template/soil interface.

The relationship of piston pressure to template pressure, and the compaction pressures selected are shown in Table 3. Maximum compaction pressure applied is comparable to that exerted by a typical off-road vehicle.

Table 4: Piston and Template Compaction Pressure

Pressure at Piston ($1.0\ cm^2$)	Pressure at Soil Surface ($167.7\ cm^2$)
$0.0\ kg/cm^2$	$0.0\ kg/cm^2$
$240.0\ kg/cm^2$	$1.4\ kg/cm^2$
$400.0\ kg/cm^2$	$2.4\ kg/cm^2$

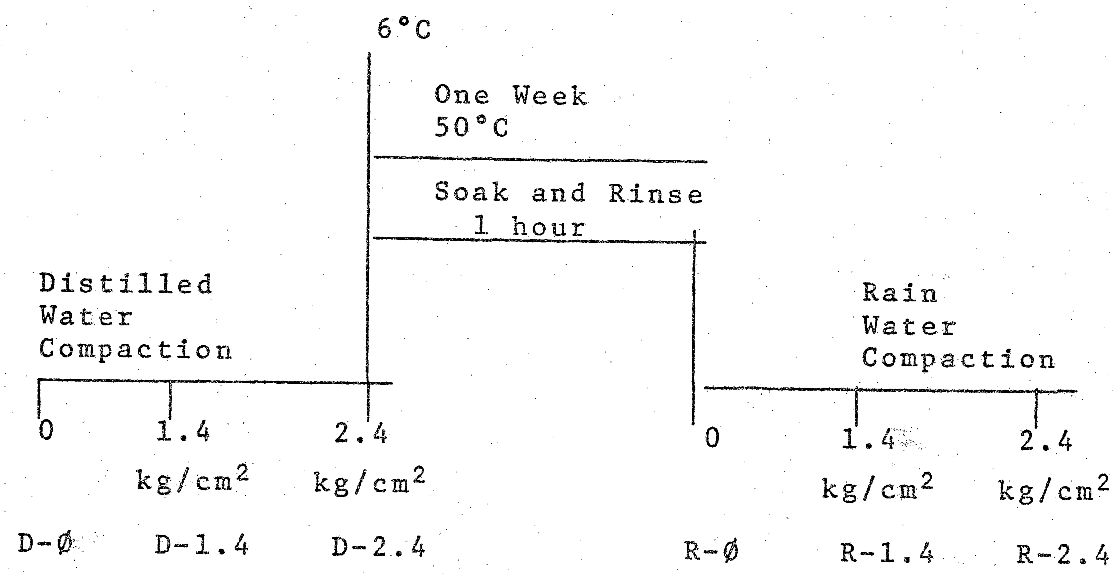
After soil compaction, the pots were placed in the greenhouse at an average temperature of 24°C over a 14-day germination period. The soil in all pots was brought to field capactiy on alternate days using rain water and distilled water respectively for the two sets of three pots for each of the six species.

Observations were made on a daily basis each evening and germination results tabulated for all pots. The flow diagram in Fig. 9 shows pre-treatments applied before the 14-day germination period. Pre-treatments for this portion of the study are coded in Table 4.

Table 4: Code Symbols for pre-germination treatments of seeds used in soil compaction and rainwater/distilled water studies as outlined in Fig. 9

Code		Treatment
D-Ø	:	Application of distilled water with no soil compaction.
D-1.4	:	Application of distilled water with 1.4 kg/cm^2 soil compaction.
D-2.4	:	Application of distilled water with 2.4 kg/cm^2 soil compaction.
R-Ø	:	Application of rainwater with no soil compaction.
R-1.4	:	Application of rainwater with 1.4 kg/cm^2 soil compaction.
R-2.4	:	Application of rain water with 2.4 kg/cm^2 soil compaction.

Figure 9: Schema for studies on effect of compaction and rain water vs. distilled water.



RESULTS

I. Results of Germination Testing in Selected Tempertures

All species exhibited greater or lesser percent germination depending upon pre-germination treatment. Also rates of germination varied with different pre-germination treatments and this phenomenon also varied with the species. Maximum percent seed germination for all pre-germination treatments for the six species are recorded in Table 6. Germination rates are shown graphically in Figures 10-32.

Table 6: Maximum percent (%) germination at selected temperatures after 14 days: A = *Allionia incardata;* B = *Amaranthus fimbriatus;* C = *Bouteloua barbata;* D = *Eriogonum deflexum;* E = *Eriogonum nidularium;* F = *Pectis papposa*. (N = 30 seeds for each treatment per species).

1.) Germination Temperature: 40°C

SPECIES	TREATMENTS							
	6	6W	6S	6SW	50	50W	50S	50SW
A	0	0	0	0	0	0	0	0
B	20	33	27	33	50	100	37	63
C	0	0	0	0	0	0	0	0
D	0	0	10	47	0	0	13	33
E	3	0	3	20	0	0	13	33
F	3	0	0	0	0	0	0	7

2.) Germination Temperature: 35°C

A	0	0	0	0	0	0	3	0
B	0	7	17	13	27	67	87	100
C	0	0	0	0	0	0	0	0
D	0	0	0	3	0	0	17	17
E	0	0	0	3	0	0	0	7
F	0	0	3	7	10	3	13	17

3.) Germination Temperature: 30°C

A	0	0	7	0	0	0	0	0
B	0	0	0	0	0	13	0	3
C	0	3	0	0	0	0	7	0
D	0	0	3	7	0	0	10	30
E	0	0	50	77	0	7	17	23
F	10	7	10	7	13	23	0	17

Table 6: continued

4.) Germination Temperature: 25°C

SPECIES	TREATMENTS							
	6	6W	6S	6SW	50	50W	50S	50SW
A	0	0	0	0	3	0	0	0
B	0	0	0	0	3	0	3	0
O	0	0	0	0	0	0	0	0
D	0	0	3	17	0	0	3	0
E	3n	10	20	23	17	13	20	10
F	3	3	3	0	0	7	7	0

5.) Germination Temperature: 20°C

A	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0
D	10	47	27	43	30	43	30	77
E	70	100	77	97	93	100	100	57
F	0	0	0	0	0	0	0	0

6.) Germination Temperature: 15°C

A	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0
D	100	100	100	100	53	100	23	100
E	60	100	100	80	100	100	37	23
F	0	0	0	0	0	0	0	0

7.) Germination Temperature: 10°C

A	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0
D	100	100	100	100	100	100	100	100
E	47	73	100	100	47	87	77	100
F	0	0	0	0	0	0	0	0

The data from Table 4 show that optimal treatments of seeds of each species for maximum germination.

a.) *Allionia incarnata* L.:

Optimum germination temperatures for *Allionia* was 30°C after scarification only (pre-germination treatment 6S). Although percent germination at this temperature, and for this pre-treatment, was quite low (7%), other seeds lots pre-treated in different ways showed no germination at all.

Time rates of germination of *Allionia* are graphically shown in Figure 10 below for the three pre-treatments that were successful.

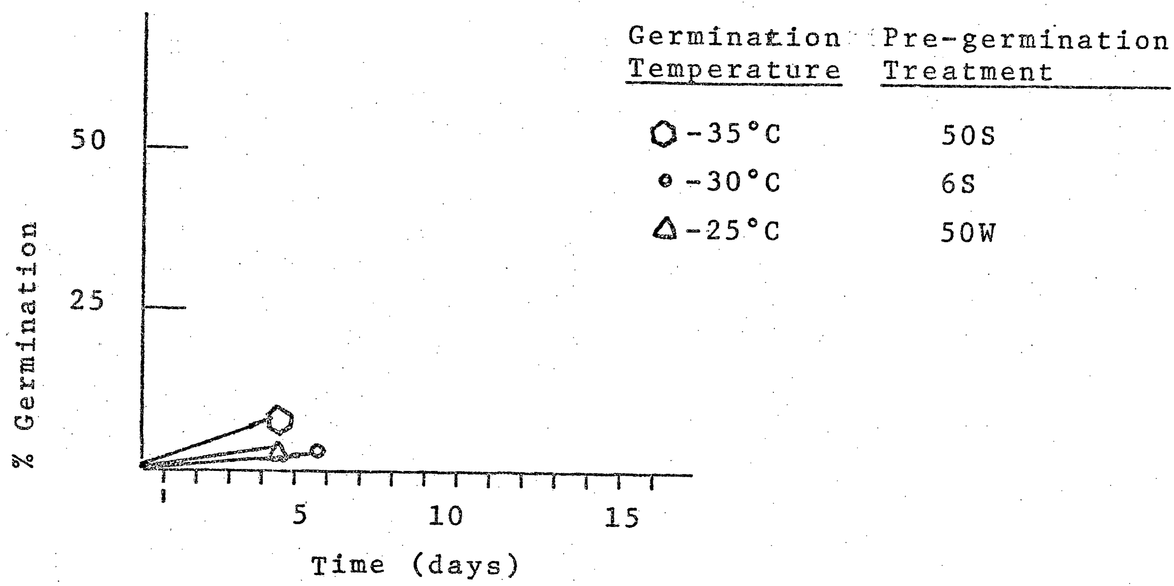
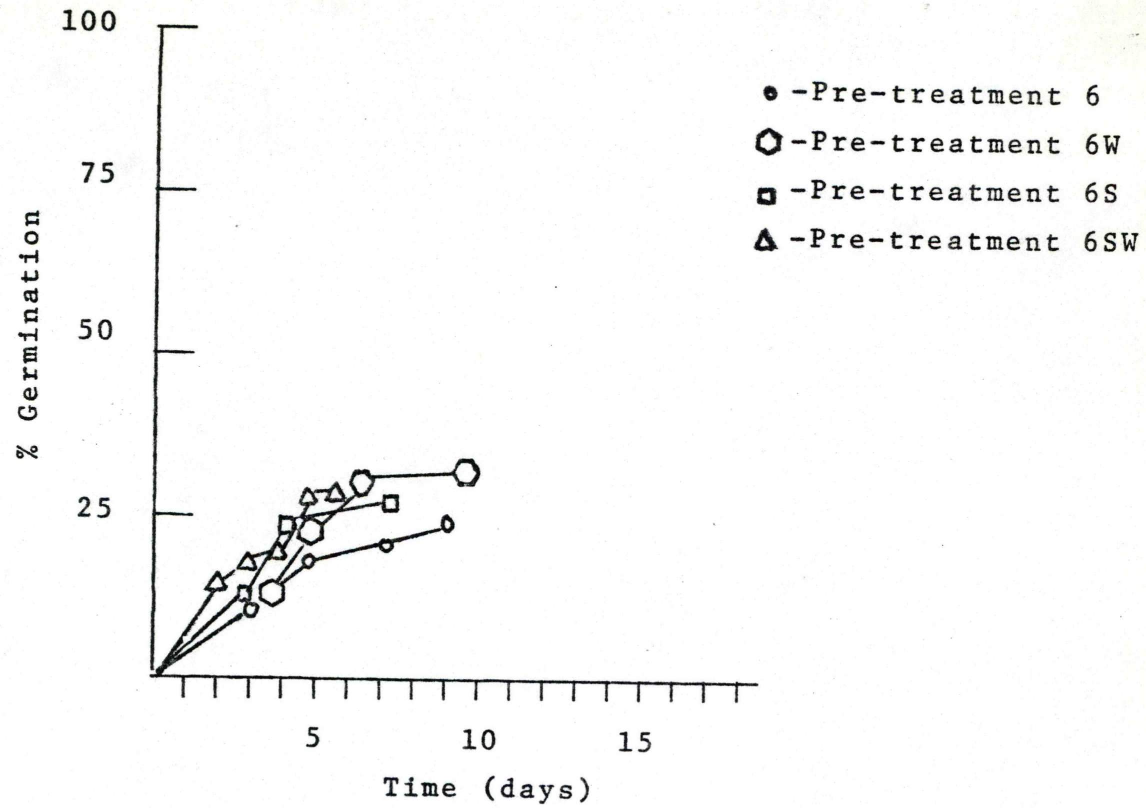


Figure 10: Germination Pattern of *Allionia incarnata* at various Germination Temperatures.

At these temperatures, germination occurred on the fourth and fifth day of the study period and for all treatments respectively.

b.) *Amaranthus fimbriatus* (Torr.) Benth:

Amaranthus seeds germinated maximally at 40°C, and while percent germination was highest for pre-treatment consisting of heating to 50°C followed by soaking and rinsing (pre-germination treatment 50W), it was also substantial for all other seed lots pre-treated differently. Seeds which were only chilled (pre-treatment 6) germinated only at 40°C. As germination temperature decreased, percent germination generally decreased. At 35°C, the seed lot with the highest germination had been subjected to heating to 50°C, scarification, and soaking and rinsing, (pre-germination treatment 50SW). Germination dropped off rapidly at lower temperatures. Data on schedules of germination at each temperature are reported graphically in Figures 11-14. Rates of germination in the seed lots variously pre-treated are somewhat variable, but the data show that pre-heating seeds at 50°C, regardless of other subsequent pre-germination treatments, yield consistent high results in germination temperatures of 40 and 35°C. In germination temperatures 30 and 25°C, only seed lots pre-treated at 50°C showed any germination.



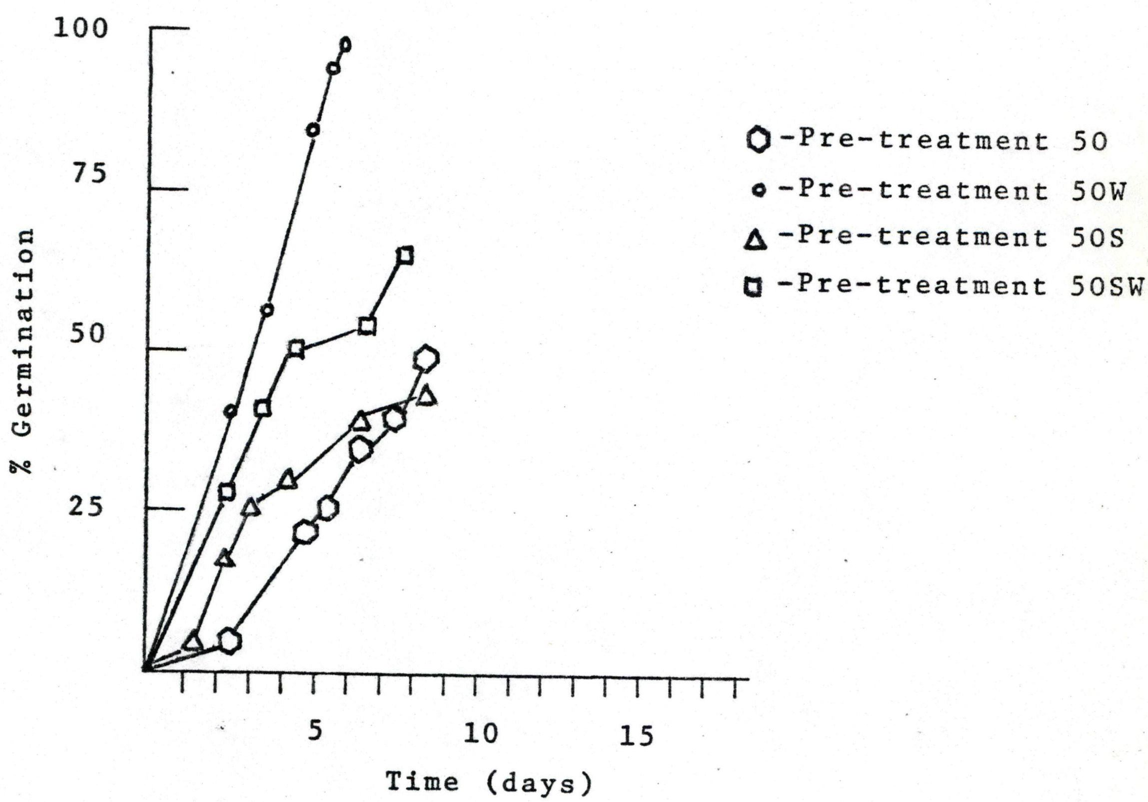


Figure 11: Germination Pattern of *Amaranthus fimbriatus* at 40°C.

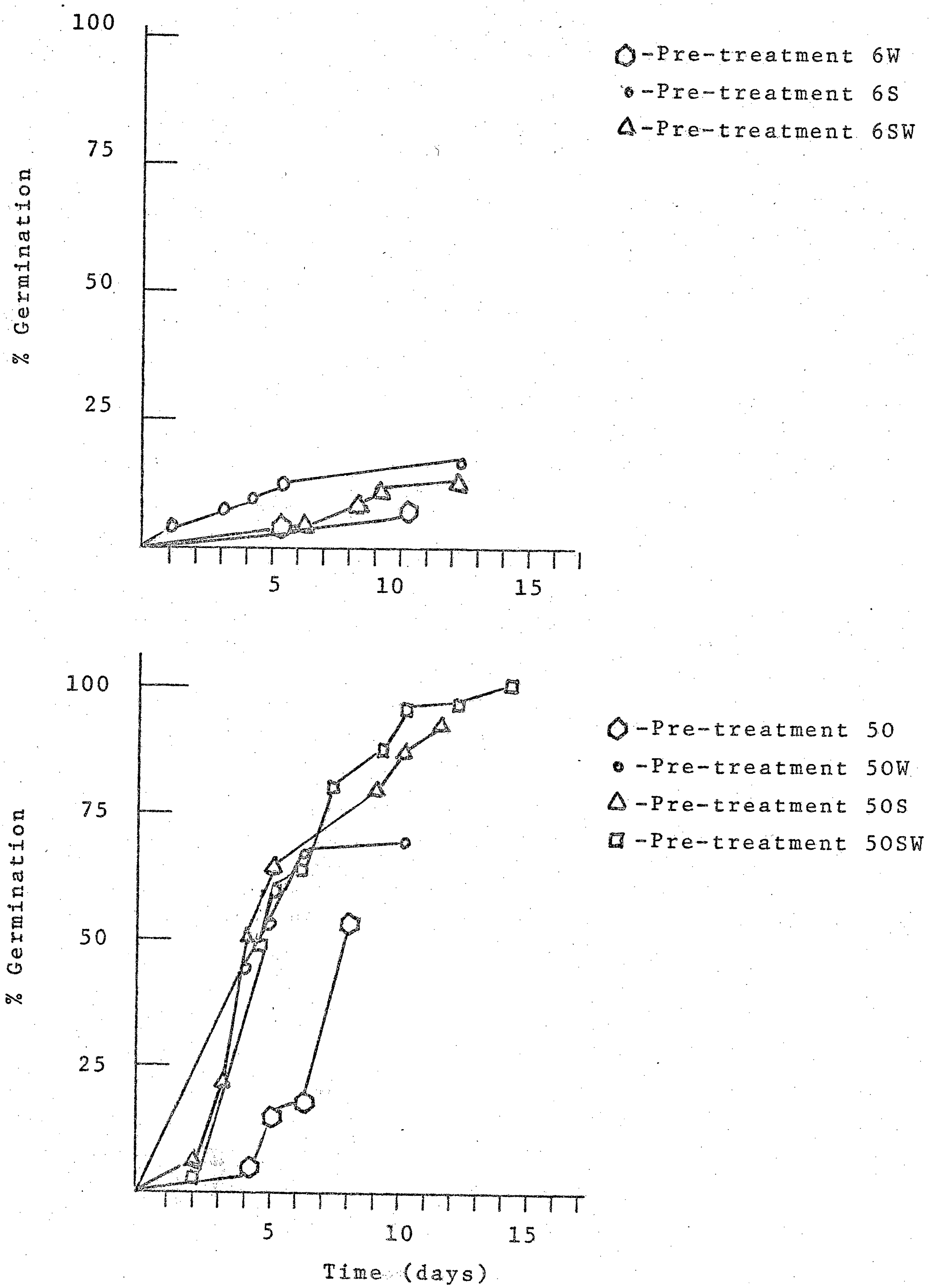


Figure 12: Germination Pattern of *Amaranthus fimbriatus* at 35°C

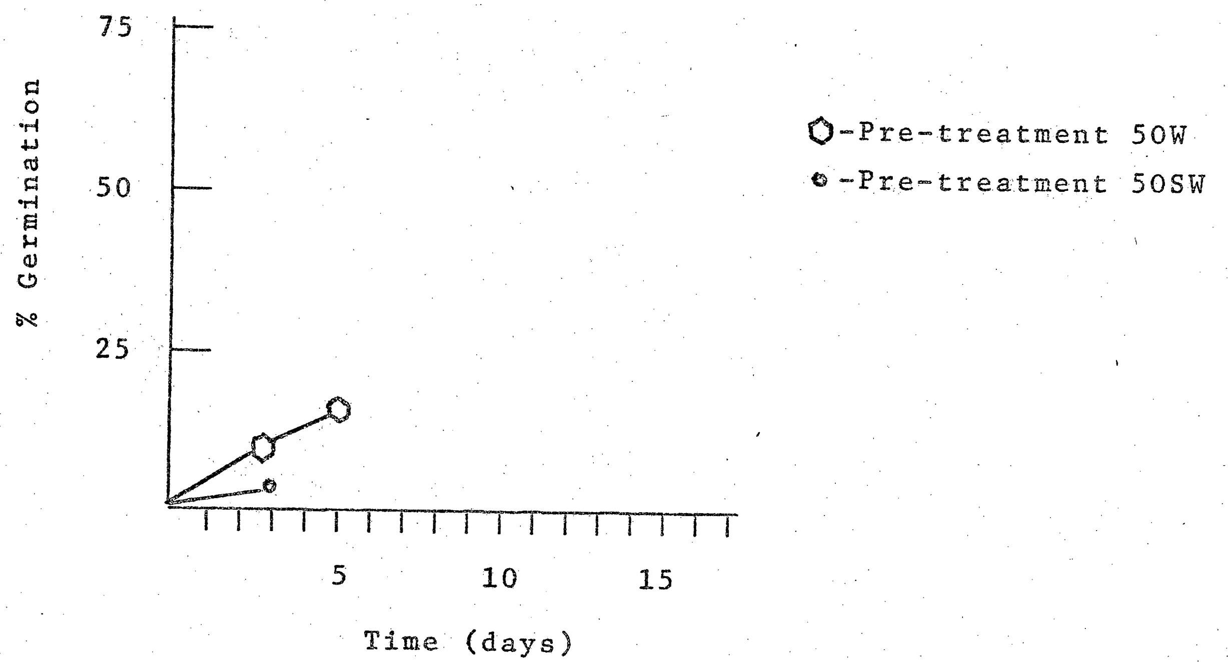


Figure 13: Germination Pattern of *Amaranthus fimbriatus* at 30°C.

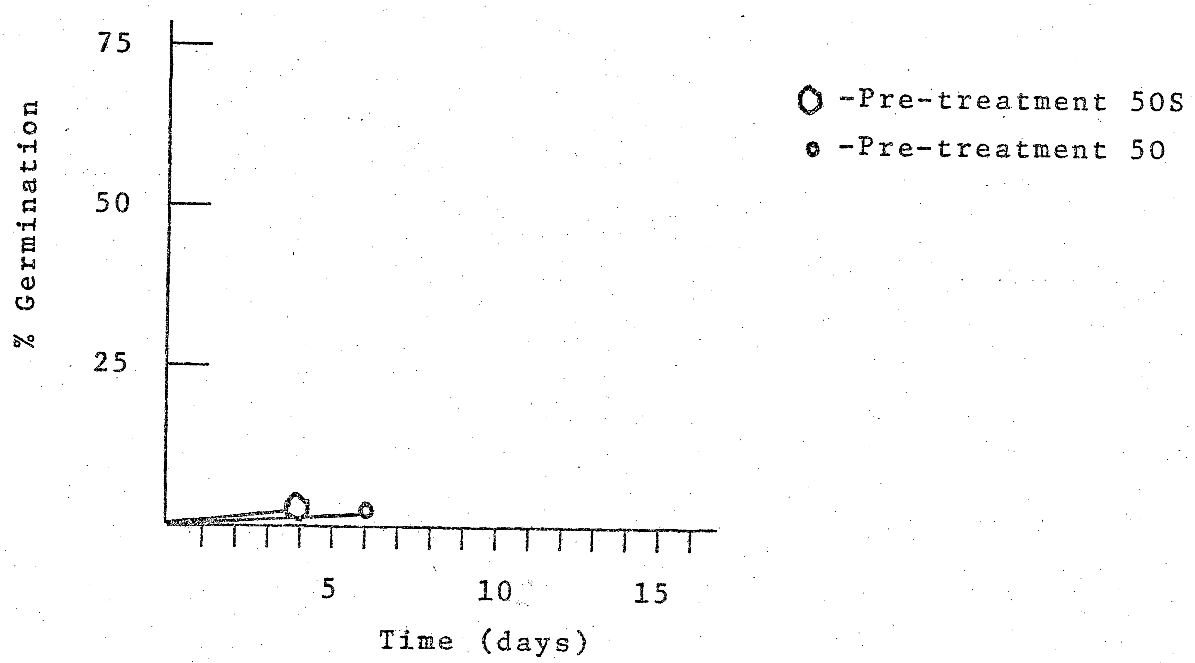


Figure 14: Germination Pattern of *Amaranthus fimbriatus* at 25°C.

c.) *Bouteloua barbata* Lag.:

Bouteloua germinated at only one temperature, 30°C, with percent germination being very low. Only two pre-germination treatments were effective and included both heating, scarification with no soaking and rinsing (pre-treatment 50S) on the one hand, and soaking and rinsing alone (pre-treatment 6W) on the other hand. Germination rates during the 14-day period at 30°C only are shown graphically in Figure 15.

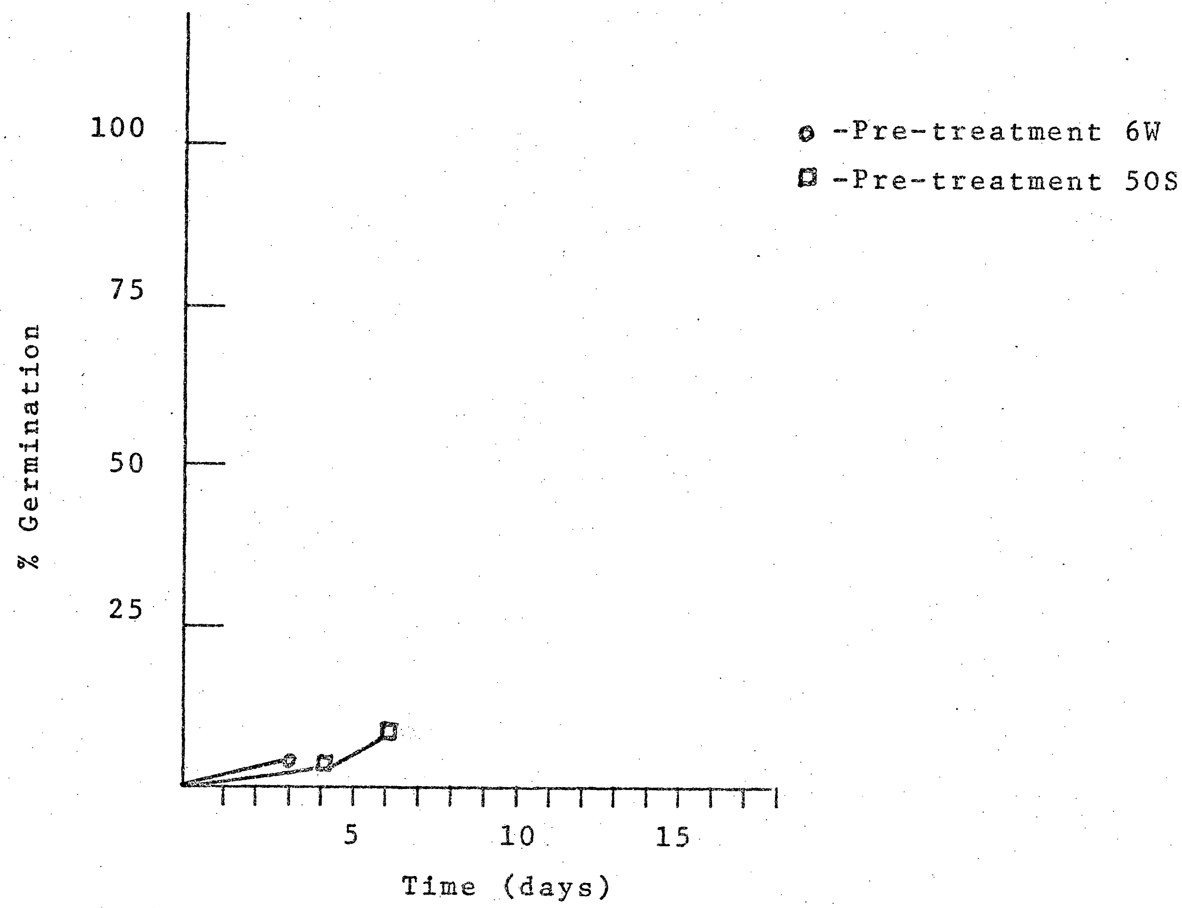


Figure 15: Germination Patterns of *Bouteloua barbata* at 30°C

d.) *Eriogonum deflexum* Torr. ssp. *deflexum*:

E. deflexum exhibited maximum germination (100%) for every treatment at temperatures of 10-15°C including the control at 10°C. At higher temperatures germination was less and was restricted to fewer differently pre-treated seed lots. In addition, the favorable influence of cooler temperature on germination rate in this species is clear as shown in Figures 16-22. At higher germination temperatures (20°C and above) the data becomes variable depending on pre-germination treatment, and lag time before the onset of germination is more pronounced.

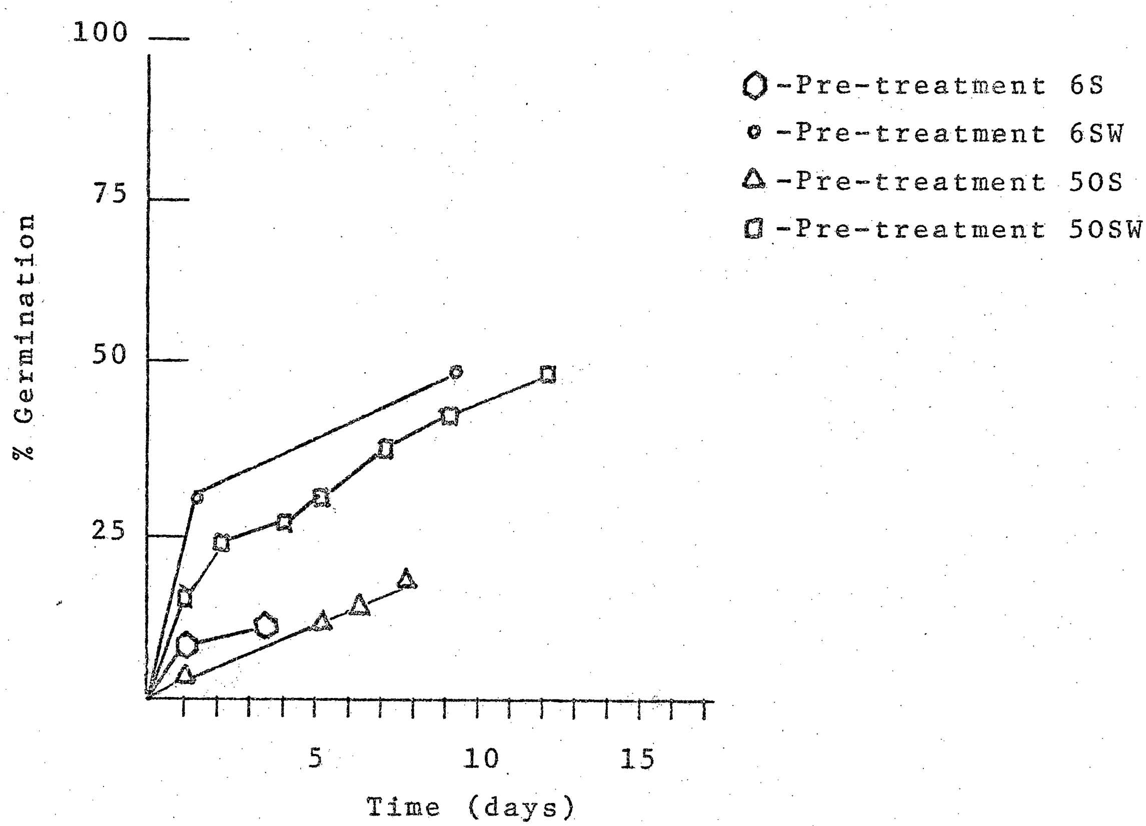


Figure 16: Germination Pattern of *Eriogonum deflexum* at 40°C.

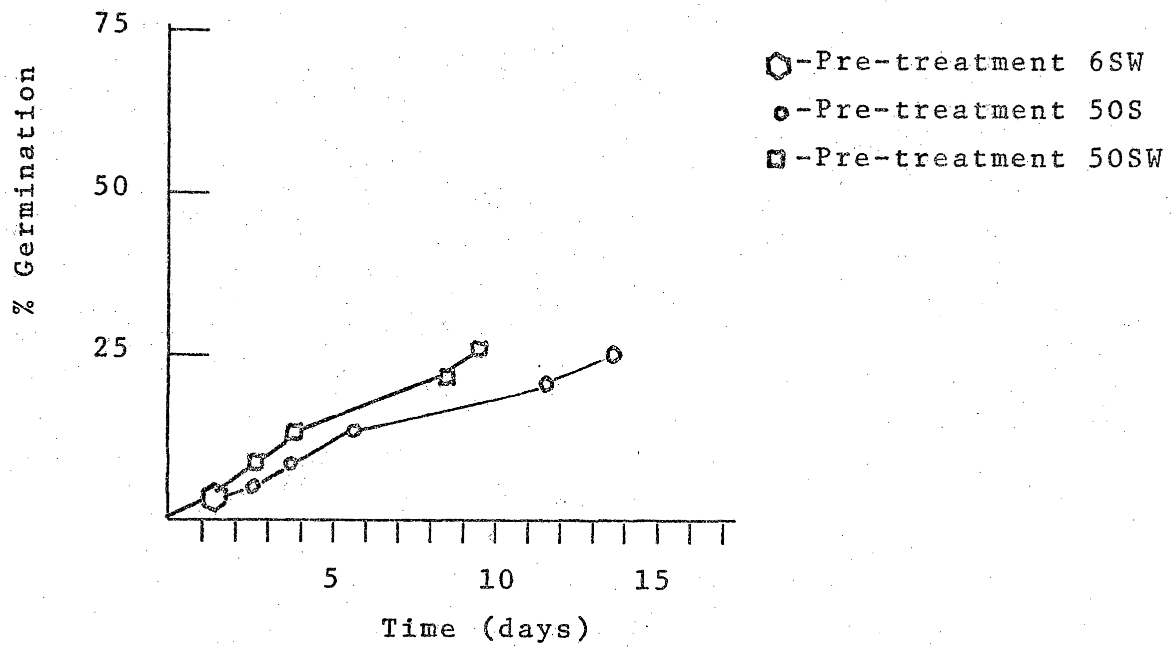


Figure 17: Germination Pattern of *Eriogonum deflexum* at 35°C.

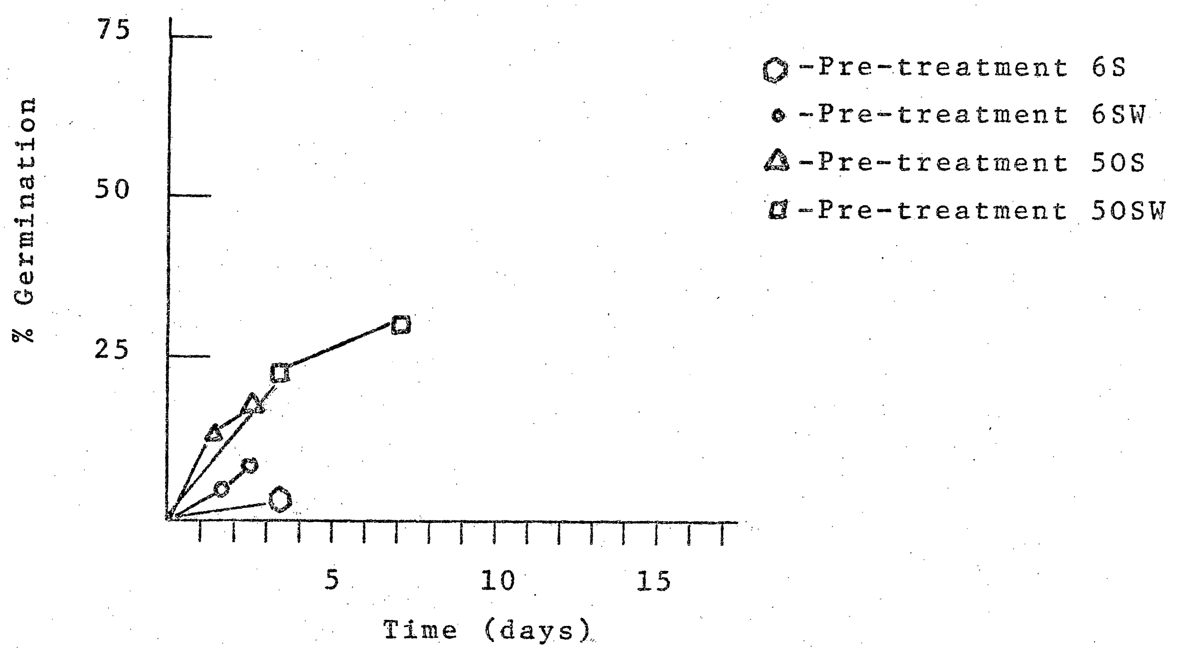


Figure 18: Germination Pattern of *Eriogonum deflexum* at 30°C.

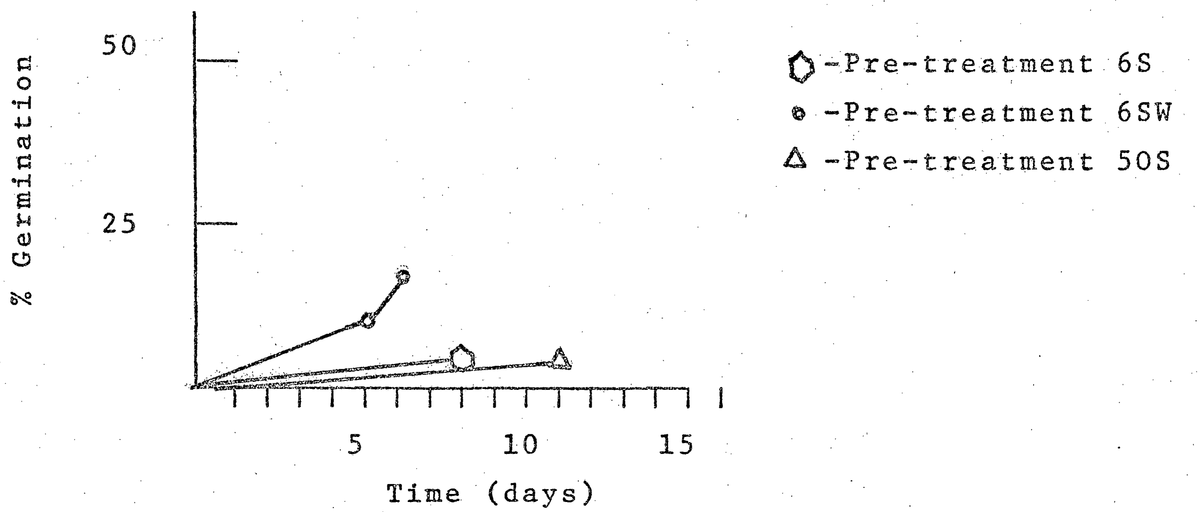


Figure 19: Germination Patterns of *Eriogonum deflexum* at 25°C

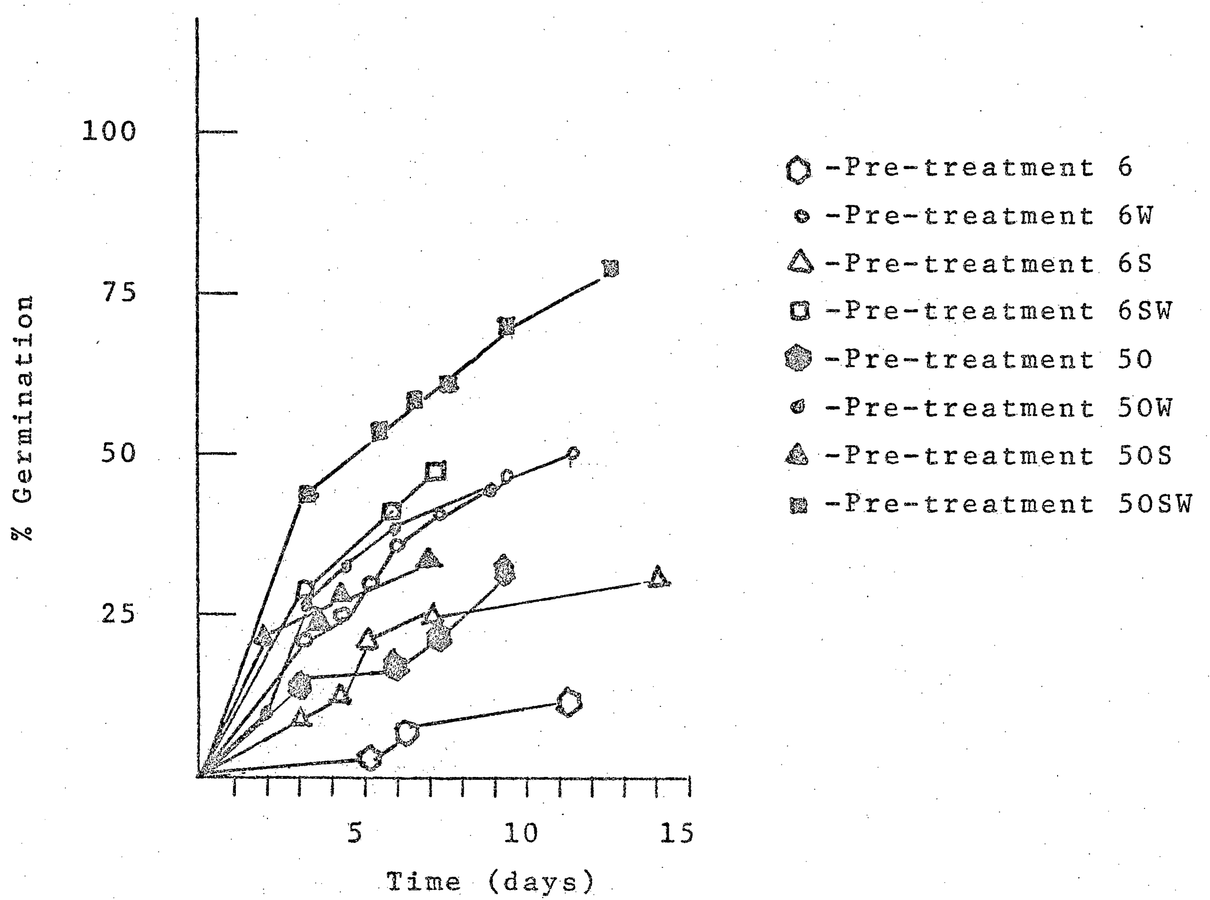


Figure 20: Germination Pattern of *Eriogonum deflexum* at 20°C
e

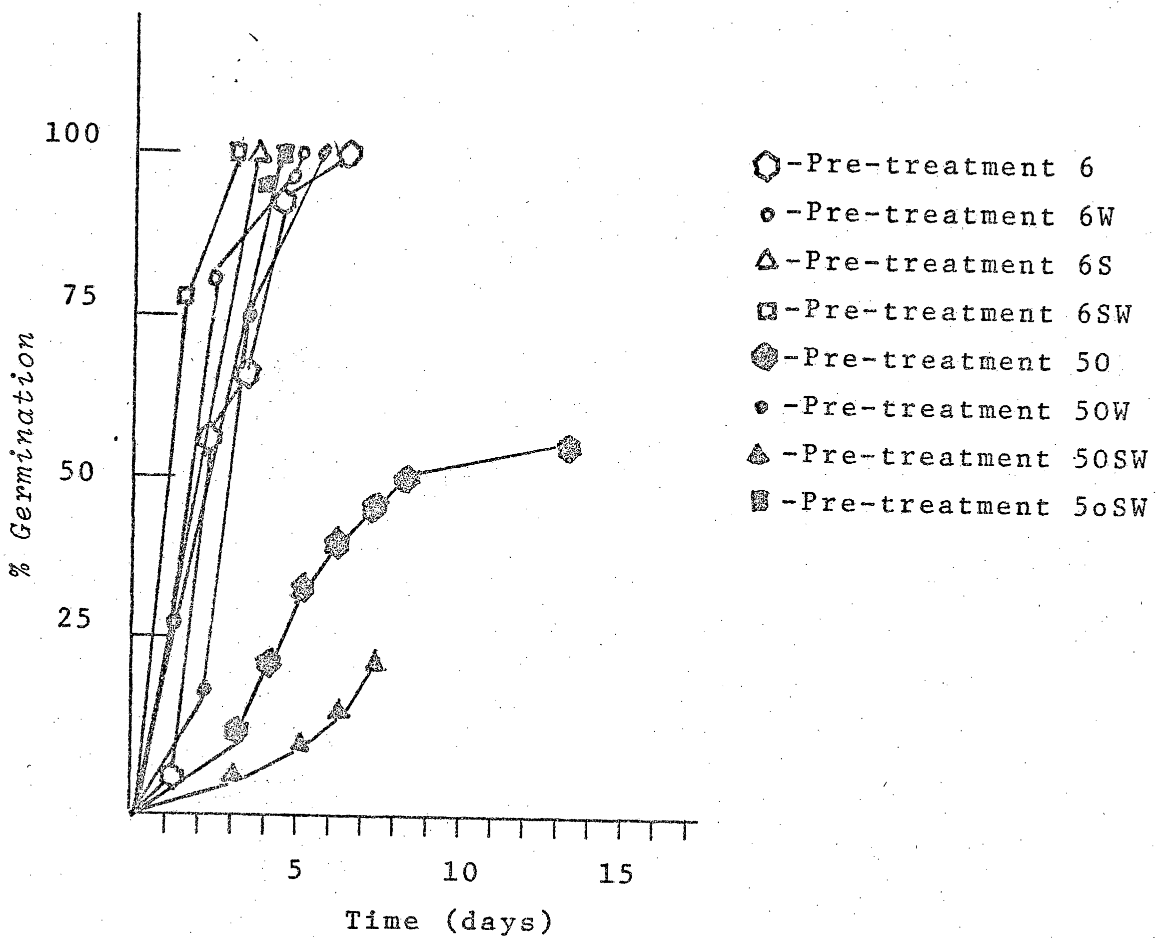


Figure 21: Germination Patterns of *Eriogonum deflexum* at 15°C

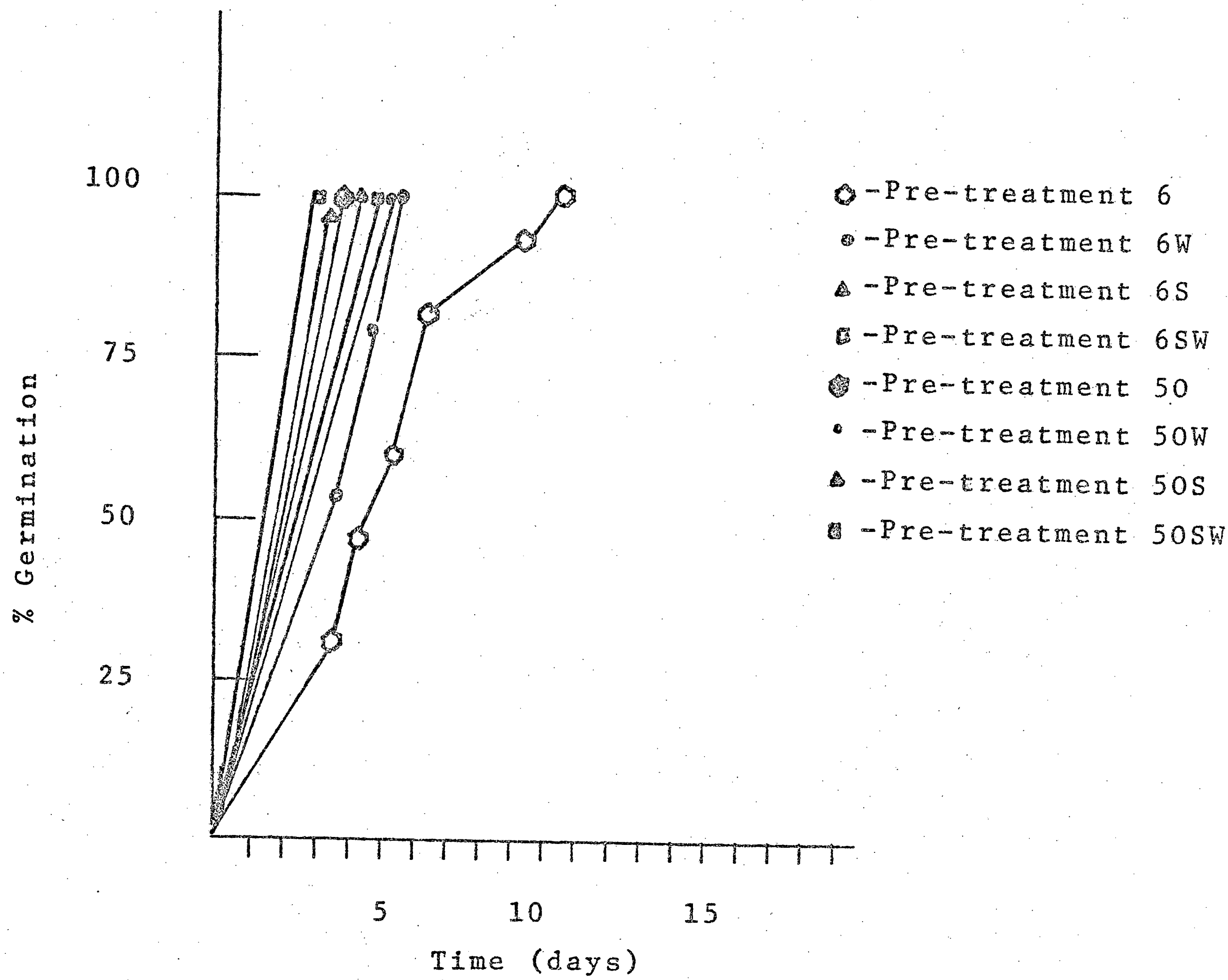


Figure 22: Germination Patters of *Eriogonum deflexum* at 10°C

e.) *Eriogonum nidularium* Cov.:

Germination patterns in *E. nidularium* were quite similar to those of *E. deflexum* with maxiumum germination occurring at 10°C. The similarity of the germination patterns between the two species is evident when Figures 23 - 28 are compared. with those above for *E. deflexum*.

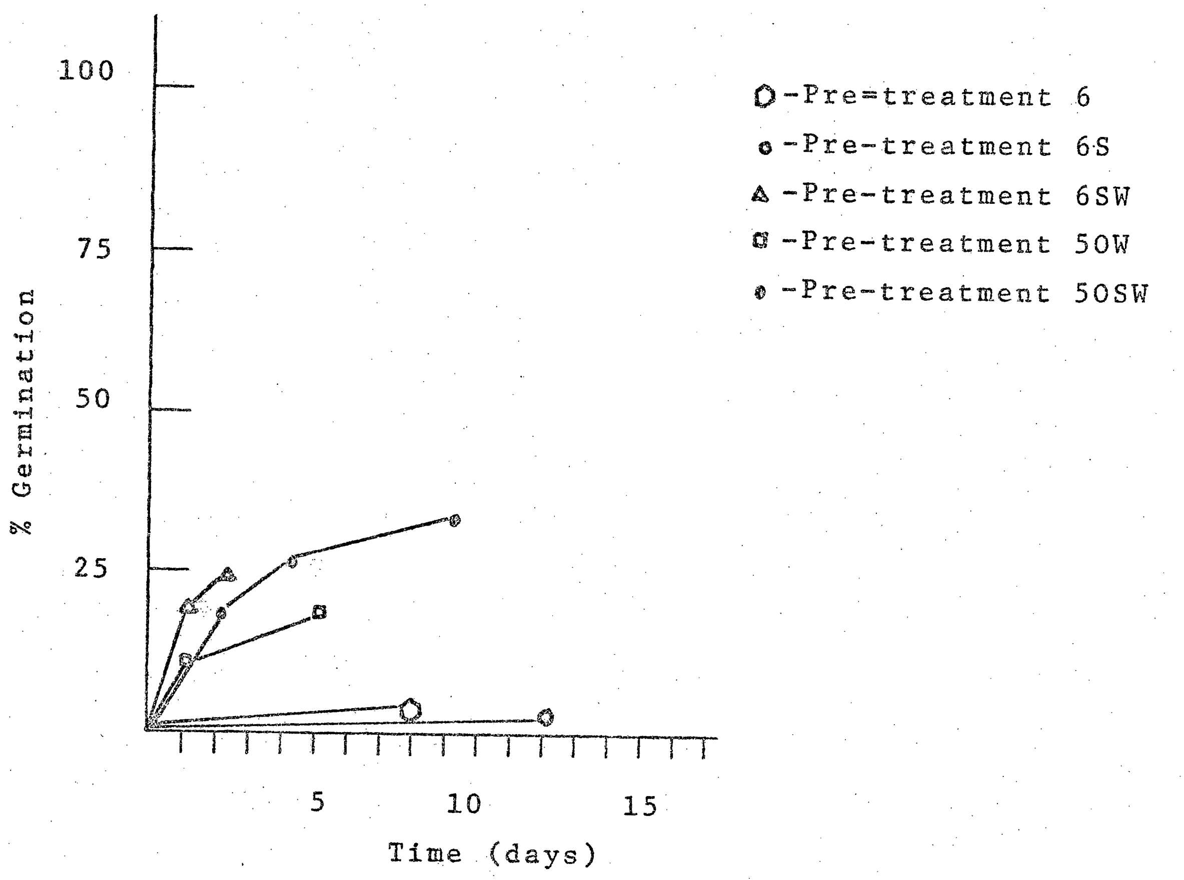


Figure 23: Germination Patterns of *Eriogonum nidularium* at 40°C

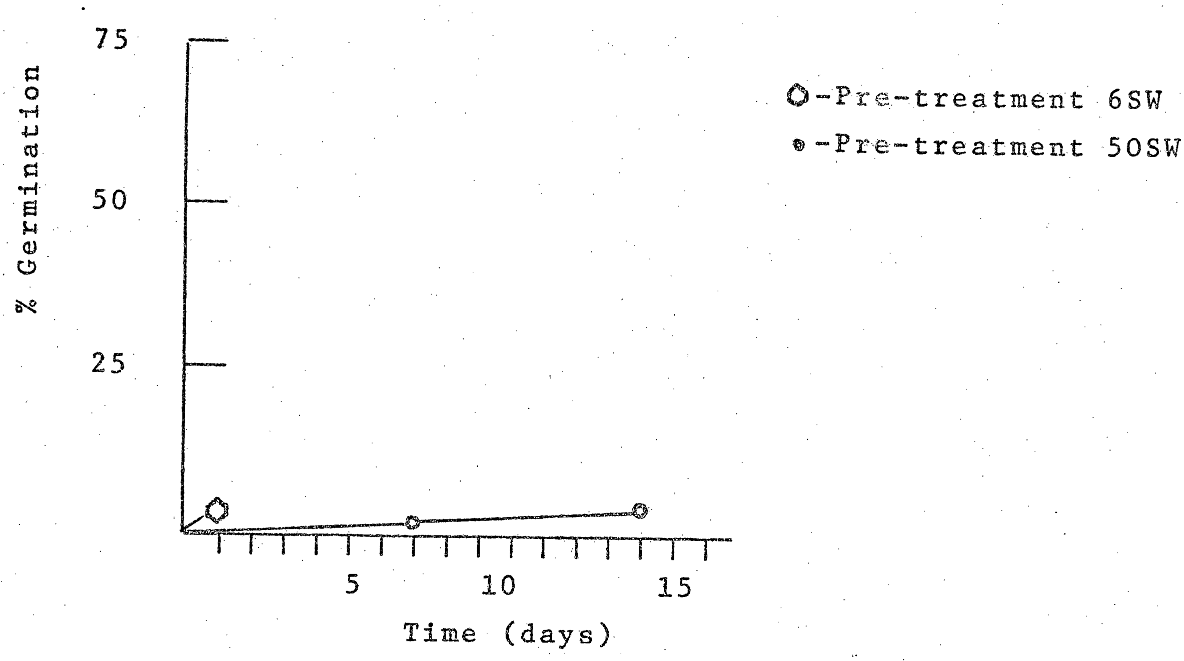


Figure 24: Germination Patterns of *Eriogonum Nidularium* at 35°C

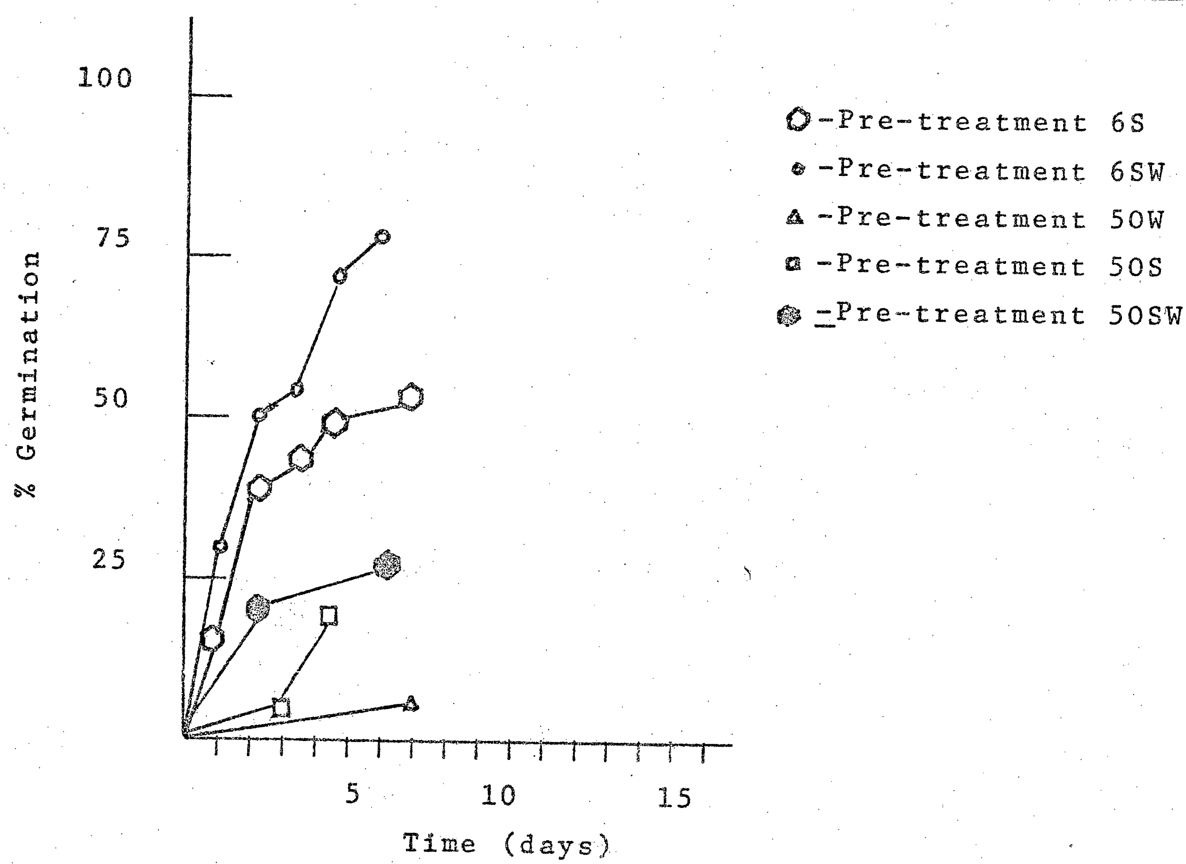


Figure 25: Germination Patterns of *Eriogonum nidularium* at 30°C.

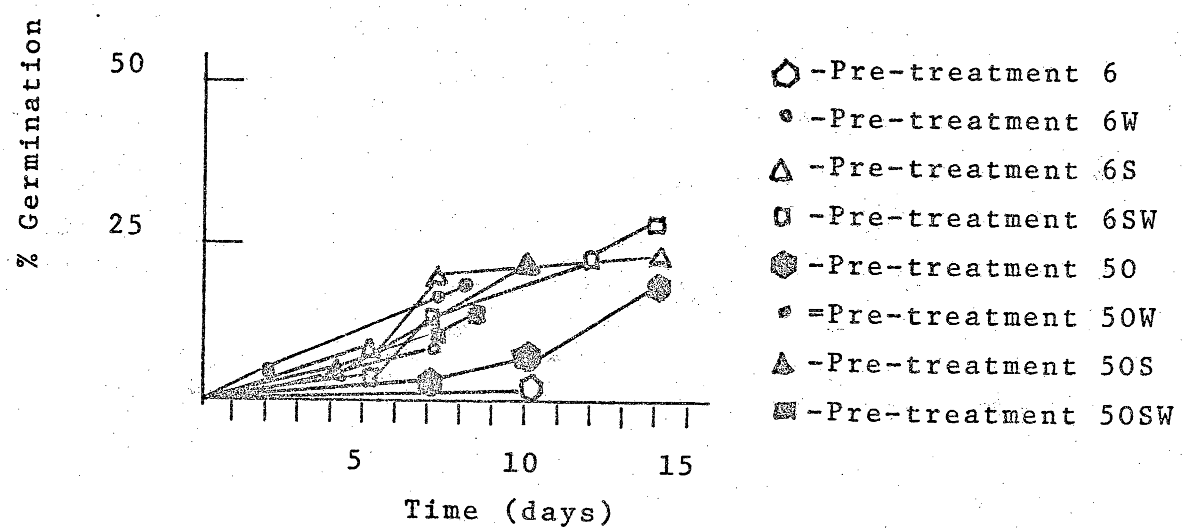


Figure 26: Germination Patterns of *Eriogonum nidularium* at 25°C

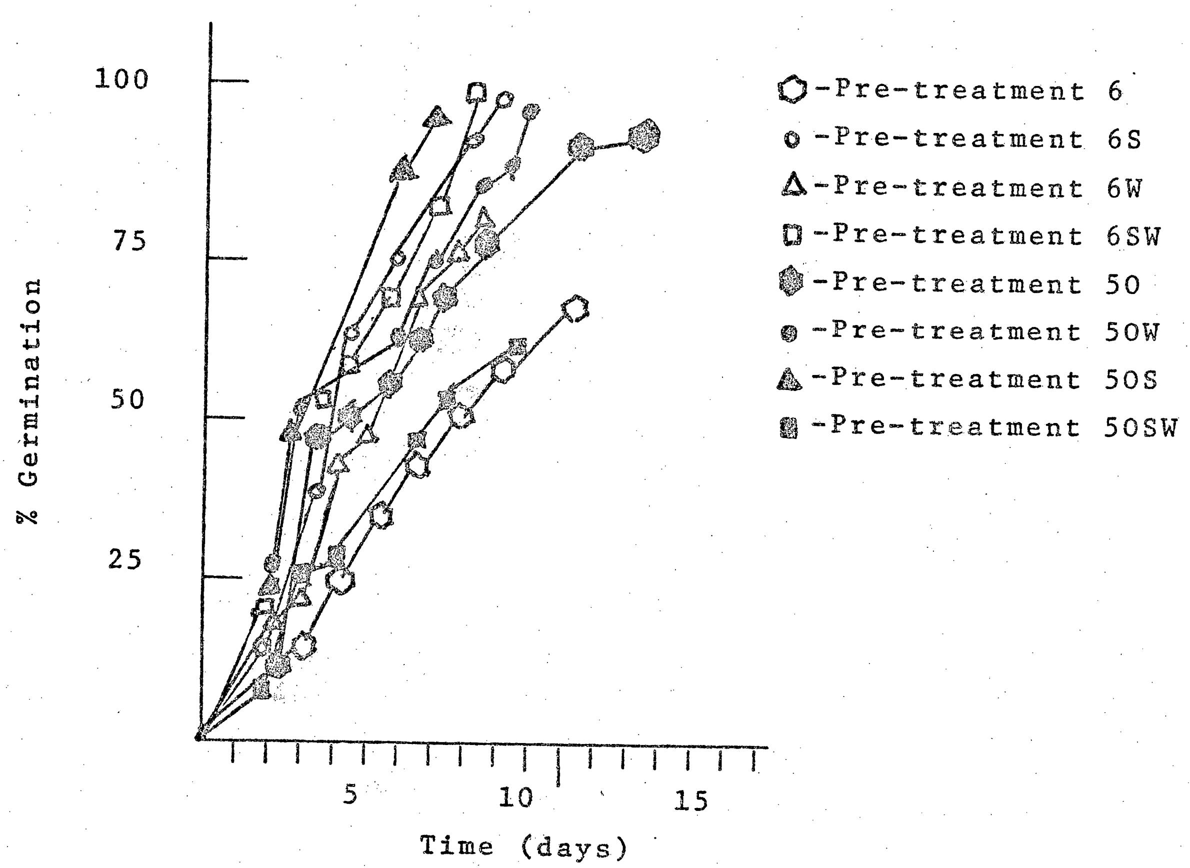


Figure 27: Germination Patterns of *Eriogonum nidularium* at 20°C

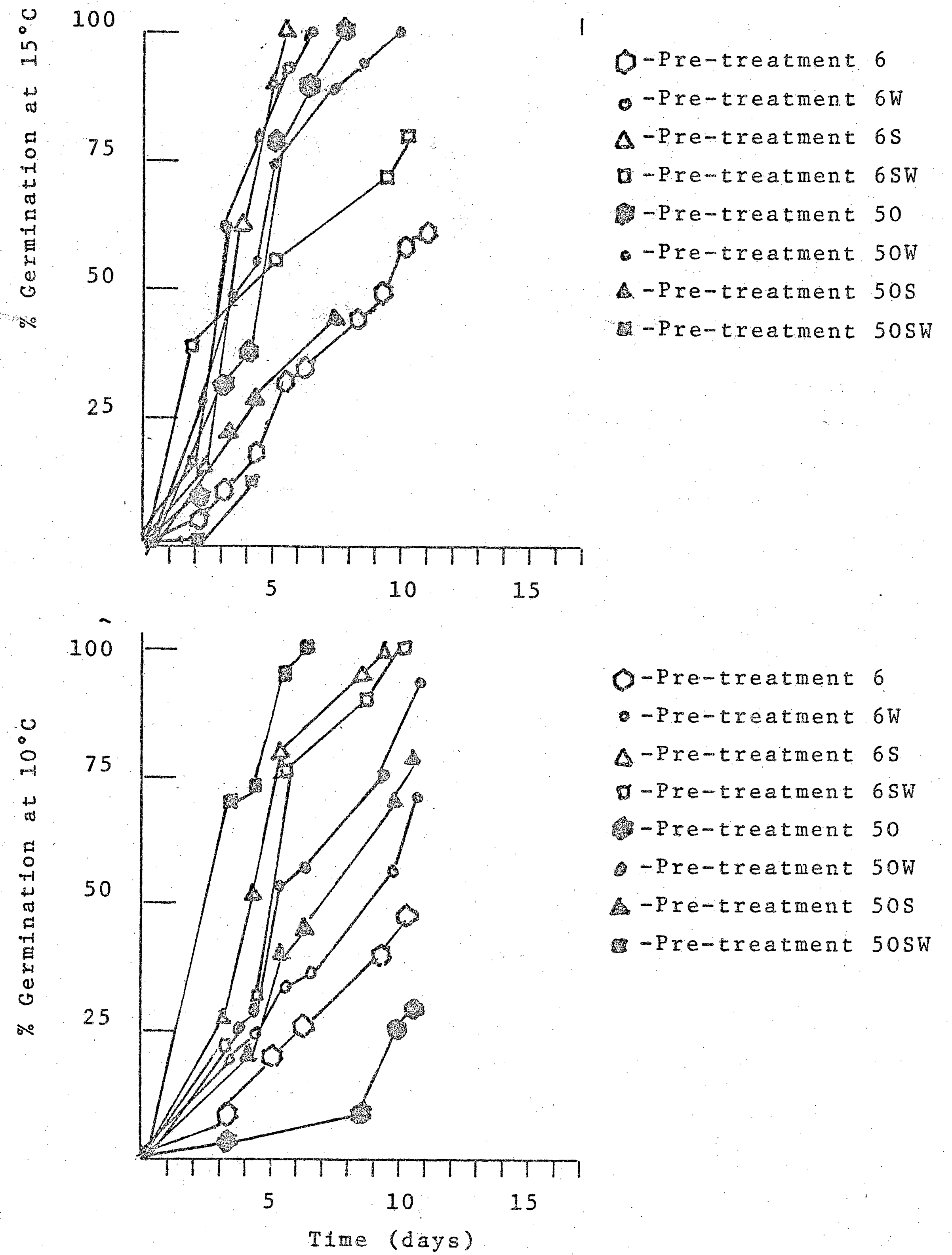


Figure 28: Germination Patterns of *Eriogonum nidularium* at 15°C

f.) *Pectis papposa* Harv. and Gray ex Gray:

Pectis exhibited a germination pattern with no sharp correlation with temperature. However, maximum germination occurred at 30°C. The most appropriate pre-germination treatment appears to have been heating to 50°C, no scarification, and soaking and rising (Treatment 50SW). Although percent germination was relatively low, there appeared to be little delay in the onset of germination, with germination rates more or less constant until germination ceased. This is shown in Figures 29-32.

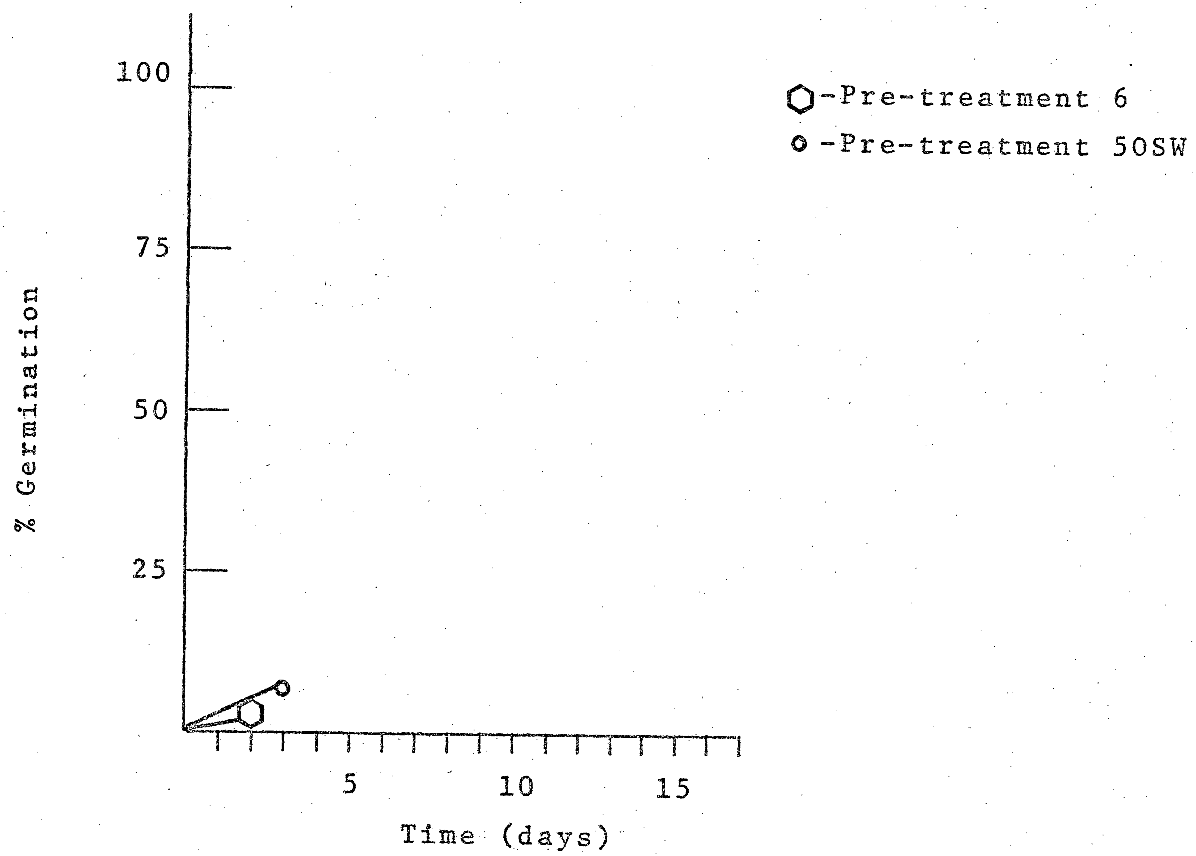


Figure 29: Germination Patterns of *Pectis papposa* at 40°C.

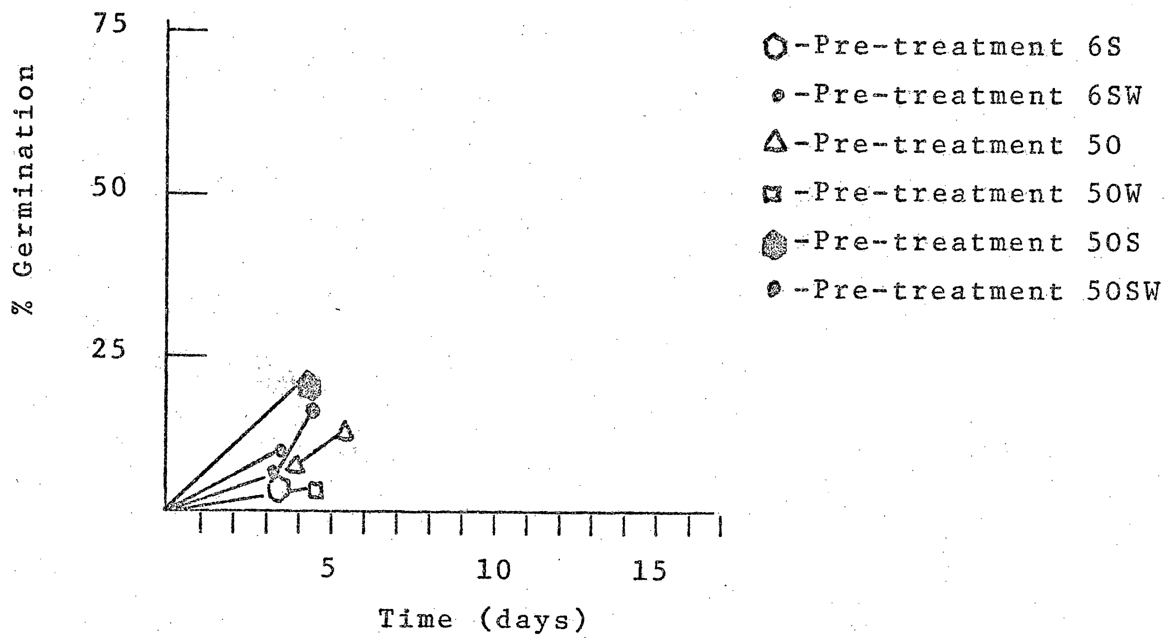


Figure 30: Germination Pattern of *Pectis papposa* at 35°C.

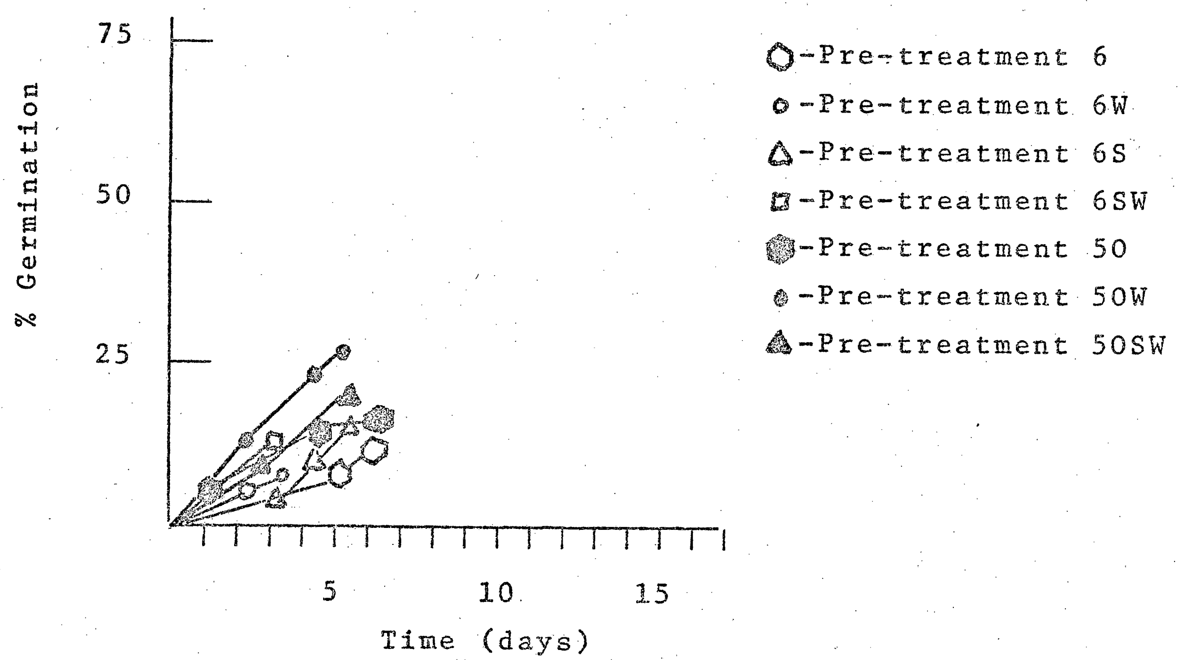


Figure 31: Germination Pattern of *Pectis papposa* at 30°C.

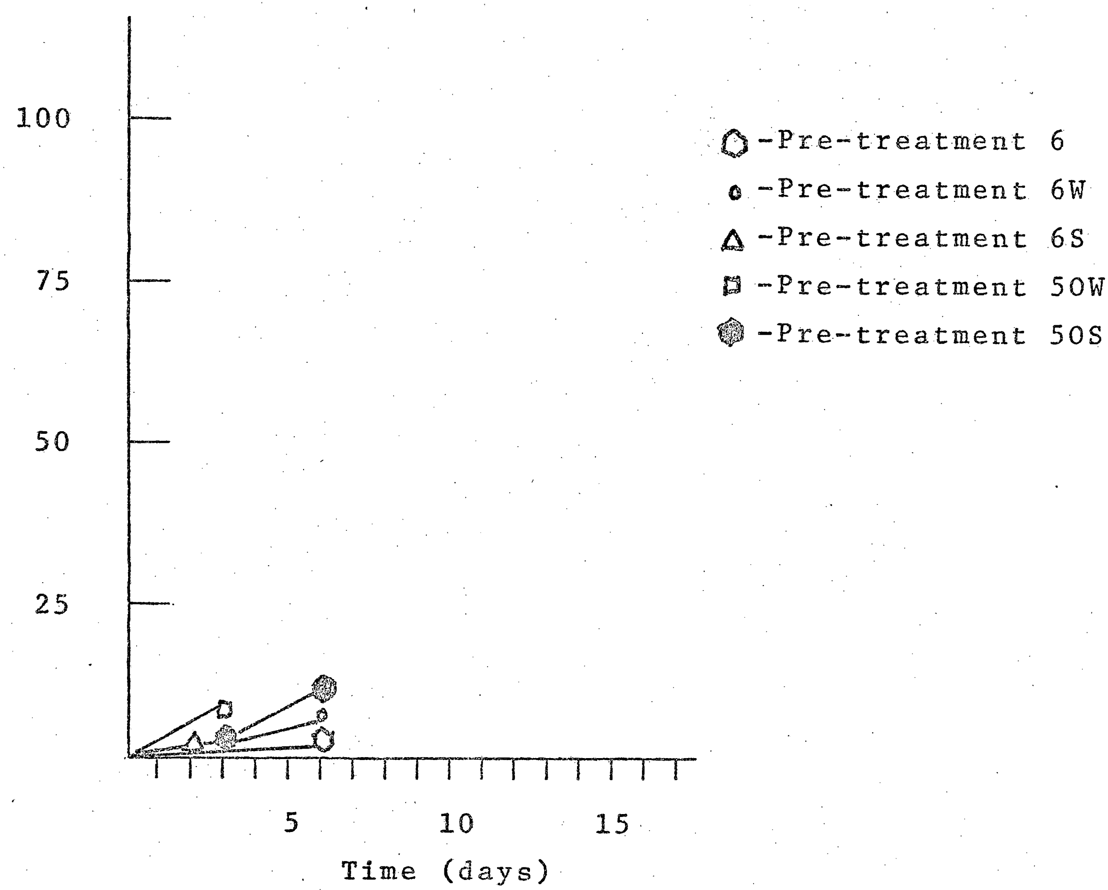


Figure 32: Germination Patterns of *Pectis papposa* at 25°C.

II. Results of Soil Compaction and Rain Water vs Distilled Water on Germination.

Table 7 shows by species the success or failure of each treatment using either distilled or rain water to enhance germination over the fourteen day test period. Under conditions of this study, there is no differential germination as a result of compaction, or due to rain water versus distilled water.

Table 7: Results of Soil Compaction and Rain Water vs Distilled Water on Germination: A = *Allionia incarnata*; B = *Ammaranthus fimbriatus*; C = *Bouteloua barbata*; D = *Eriogonum deflexum*; E = *Eriogonum nidularium*; F = *Pectis papposa* in Percent Germination. (N = 30 seeds for each treatment per species.)

SPECIES	TREATMENTS					
	D-Ø	D-1.4	D-2.4	R-Ø	R-1.4	R-2.4
A	10	7	17	10	13	3
B	13	3	0	3	10	10
C	10	3	3	13	0	3
D	13	0	0	3	3	7
E	7	10	0	10	3	3
F	0	0	0	10	3	0

DISCUSSION

The results of this study clearly place five of the six species in the categories of summer annual or winter annual plants as determined by optimum germination temperatures. Thus, *Amaranthus fimbriatus*, *Bouteloua barbata* and *Pectis papposa* are placed in the summer annual categories, while *Eriogonum deflexum* and *Eriogonum nidularium* fall into the category of winter annuals. These findings in the present study are consistent with earlier results gained by Went (1948, 1949), Went and Westergard (1949), Juhren *et al* (1956) and Tevis (1958a, 1958b) for seeds of this species. In these earlier determinations, seeds were collected from Death Valley National Monument, Joshua Tree National Monument and the Coachella Valley, but not from the East Mojave Desert. For the five species studied, the present study indicates further that their classification as winter or summer annuals holds regardless of geographical area.

Earlier determinations for unidentified *Eriogonum* ssp., resulted in the general statement that probably the whole genus is winter germinating (Went 1948). Results from the present study for two species of the genus, *Eriogonum deflexum* and *Eriogonum nidularium*, fit Wents' gerneral statement, but, obviously do not account for the numerous other species of this genus present in the southern desert regions of California.

Maximum percent germination and rates of germination for *Amaranthus fimbriatus* occur at a germination temperature of 40°C thus placing this plant in the category of summer annual. The stimulus provided by pre-germination heating to 50°C, a temperature commonly occurring in the summer in the Mojave Desert further supports this categorization. Leaching of seeds may also be of significance in promoting germination in this species, perhaps substituting in part for more elevated pre-germination temperatures. In the case of *Bouteloua barbata* the elevated pre-germination, temperature appears the most effective in promoting germination, but with the process also apparently dependent on scarification of the seed coat.

Pectis papposa, also a summer annual, exhibited the best germination after pre-treatment by heating to 50°C, while optimum temperature for germination was 30°C. In this species, leaching of the seed also is significant in promoting maximum germination.

Summer annuals included in the study, required elevated temperatures before germination began. The range of temperature requirements for actual germination may relate to different times of initial germination among these species during the warm season in natural habitats.

Eriogonum deflexum is a winter annual as supported by massive germination exhibited at 10°C regardless of pre-germination treatments. However, at higher temperatures pre-germination heating, scarification and leaching promote substantial germination. Thus, in nature this plant could exhibit some degree of germination at other times of the year due to these factors, and this may lead to confusion as to its classification as a winter annual plant.

On the other hand, *Eriogonum nidularium* appears to be less influenced by pre-germination heating when placed in higher germination temperatures, but the requirements for scarification and leaching remains effective at elevated germination temperatures. However, as for *E. deflexum*, this species is a winter annual, but with a broader range of cooler temperatures effective for maximum germination. Nevertheless, *E. nidularium* is more restricted to the designation of a winter annual than *E. deflexum*.

Allionia incarnata, the remaining species of the six considered in the present study, has not been previously studied in terms of its winter or summer annual status. In the present study resutls are somewhat puzzling in regard to its categorization. Germination of seeds of *Allionia incarnata* seems uninfluenced by pre-germination heating, but does require elevated temperatures for germination. This would indicate that the plant is a summer annual. However, this is not consistent with the plant being found growing in nature during spring of the year in the study area, nor with the findings of Went (1949) that this species germinates at higher elevations in response to late falls rains. The low germination results for *A. incarnata* indicate the requirement of some other factor necessary for germination but apparently deleted in this study.

The effects of soil compaction and the application of rain water versus distilled water show no discernable differences in germination patterns for these species, and thus are not consistent with the general findings of Tevis (1958a, 1958b), Davidson and Fox (1974), Phillips and Kirkham (1962), Klop *et al* (1967), Wilshire and Nagata (1976), Kabota and Williams (1967).

Assuming that compaction has no influence on germination in these six plants, it is expected that these species may be more successfully introduced to and established in habitats where soil compaction has occurred.

The present study, while indicating the requirements for the seasonal environmental flux of the six species considered, also points the way to continuing research on the influences of these fluxes on seed and seed-coat physiology. Further detailed studies of these aspects, coupled with the elucidation of the requirements for the seedling establishment and survival of the plants to maturity in various habitats, will be necessary to more fully understand the requirements for ecesis, the successful establishment of these plants in the habitat, for these species.

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